Domesticating the mountains: The palaeoecology of changing resource management during the Mid- to early Late Holocene in southeast Anatolia and Kurdish Iraq

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Declaration

I, Anke Lizbeth Marsh, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Abstract

This thesis sets out to answer three questions using the primary datasets of sedimentary and phytolith evidence. The questions relate to how local environmental change can be seen in these datasets, how resource and land use can be discerned in the sedimentary and phytolith records and finally, how these datasets can be used to elucidate on human modification of the environment and subsequent ecological and cultural inheritances using the framework of cultural niche construction. In addition, a new protocol for establishing land surfaces in offsite samples and differentiating been regional and local phytolith signals is also introduced. On and offsite samples were taken from two sites, Hirbemerdon Tepe in southeastern Anatolia and Bakr Awa in Iraqi Kurdistan.

The thesis concludes that the combination of the two methods provides an effective way to understand local environmental change, resource and land use. It also shows that, despite drawbacks of using offsite data, which may be fragmentary at times, sedimentary and phytolith evidence can be used to understand and describe human modification of the environment and should be considered when addressing questions about the human environment- relationship, using the cultural niche construction approach. Finally, although the land surface protocol needs much refinement, it shows much promise as a tool for understanding environmental and vegetation change as well as resource and land use.

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Part I

Introduction and background

Chapter 1

Introduction

1.1 Introduction

There has been a lot of debate over the years regarding the relationship between humans and their environments, particularly in areas and periods where there is much cultural change. This is particularly true of the Near East, especially at the end of the third millennium, where climatic conditions appear to be becoming drier, farming more precarious and sites across the region appear to contract or be abandoned entirely (see for instance: Weiss 2012a, Weiss *et al.* 1993, DeMenocal 2001, Ristvet and Weiss 2005). What is becoming clear is that this scenario is much more complicated: it is not simply a case of societies reacting to changing / deteriorating environmental conditions, nor is it that clear that how the environment changed was uniform across the region (see for instance: Kuzucuoğlu 2007, Roberts *et al.* 2011a, Rosen 2007).

The premise of this PhD thesis is that the discussion regarding the end of the third millennium needs to be more nuanced, that local (as opposed to regional or global) evidence needs to be collected and analysed, in order to understand how the climate/environment changed in very different parts of the Near East and that societies, while sometimes reacting and adapting to climate and environmental change, often are more active players, actively altering their environments in a way that triggers change within that environment and microclimate.

The research in this thesis uses environmental evidence (sediments and phytoliths) combined with other available datasets (archaeological, macrobotanical, faunal) in order to understand how the environment changed on a local scale and to understand how societies used and managed their resources, thus modifying their local environments, using the framework of cultural niche construction. Through the combination of environmental evidence and cultural niche construction theory, a better understanding of environmental and cultural change during this period can be obtained.

1.2 Research questions and methods

The primary methods used to answer the research questions were sedimentary and phytolith analyses. Both methods, as is discussed in Chapter 5, provide good evidence for the understanding of climatic and environmental change, as well as human modification to the environment. These methods, however, are not often combined, which is surprising given that they can help to corroborate each other. This is especially true for offsite studies. Sedimentary evidence can shed light on the hydraulic history of a river and associated plain which in turn can give information on sedimentation processes which, for example, may have been modified by human intervention. On the other hand, phytolith analysis can give information on the botanical history of the plain, providing both local, *in situ* signals as well as more regional signals (Delhon *et al.* 2003). This information helps us to understand land use patterns and vegetation shifts, which could be the result of human intervention (such as land clearance for farming and grazing) and which impacts the sedimentary record.

In addition, a new protocol for differentiating land surfaces using phytolith evidence is introduced. The key to this land surface protocol is differentiating between local and regional signals in the phytolith evidence, based on taphonomical parameters. This protocol is based on the premise that phytoliths that are transported downstream in rivers will behave as other sedimentary particles. In other words, that they are, while being transported, simply another silt sized silica clast subject to the same patterns of fracturing and abrasion. The protocol is still nascent, and further development will include a method of recording fracturing and abrasion of the phytoliths in order to understand their erosional and depositional histories. Thus, being able to differentiate between those eroded phytoliths and those deposited *in situ*, would aid in the distinguishing between regional signals from local signals, thus providing a more detailed picture of vegetation change.

The research questions that this thesis will address are as follows:

1. How are local and regional environmental changes reflected in the sedimentary and phytolith records?

This question addresses the need to understand local variations in climate and environment, using local proxies. In both of the regions studied (discussed below), there has been limited environmental research and as such, research conducted in other parts of the Near East, usually the Levant and southern Mesopotamia, have been used to provide an environmental background. This is unfortunate, because the evidence collected from areas such as the Levant and southern Mesopotamia, and scenarios drawn from this evidence, will not actually reflect what is happening in these study areas. This is mainly because the environments are completely different and thus will have different processes acting on them (discounting any human modification). The Levant and southern Mesopotamia are, generally speaking, far more arid, flatter and at lower elevations. Southern Mesopotamia, for instance, is a wide, low lying alluvial plain, with less precipitation. The study areas, on the other hand, are montaine alluvial settings with narrow alluvial plains and with higher precipitation. As such, there will be different sedimentary and fluvial processes, and different vegetation. In addition, climate patterns will also vary. This will impact not only how any possible global aridification trends impact this area but also what kinds of human modification will be carried out and what impact this will have on the environment.

As will be discussed in Chapter 5, both sedimentary and phytolith evidence are very good proxies in understanding climatic and environmental change on a more local scale. Combining the two datasets strengthens the evidence and can provide a more nuanced picture of change through a period of time. These local and semi-regional changes need to be understood in order to answer the next question.

2. What resource and land use patterns can be discerned in the onsite and offsite proxy data?

This question moves on from the first and tries to tease out more detail from the given datasets. I will also use evidence from any other datasets that might be available, such as cultural material and macrobotanical and faunal remains.

The first research question is general and looks at changes in the environment through time, this question tries to understand what decisions societies made. These could include agricultural and husbandry strategies, 'wild' resource management (such as wetlands) and so on. In an area of active use, whether through arable activities or collection and management of other resources (or usually both), there needs to be some sort of understanding of what these activities were in order to understand how societies may have modified their surroundings and what impact this could have had on the environment over time.

3. How can sedimentary and phytolith evidence be used, in conjunction with other datasets, to explain human modification of the environment and ecological and cultural inheritance as posited by cultural niche construction theory?

The idea of ecological inheritance is central to niche construction theory in general (see Chapter 4) and so it seems logical that environmental evidence be used to understand how humans use niche constructing activities to modify their environments (and pass on the knowledge to the next generation). This thesis first shows how useful the combination of sedimentary and phytolith evidence can be in the understanding of environmental change and land use strategies over time, and then shows, in the framework of cultural niche construction, how useful these methods can be in understanding human modifying behaviours and resultant ecological and cultural inheritances.

1.3 The sites: southeast Anatolia and Iraqi Kurdistan

Hirbemerdon Tepe in southeast Anatolia and Bakr Awa in Iraqi Kurdistan are environmentally similar to each other (both are montaine alluvial environments) and both are situated away from the so-called 'core' of Mesopotamia and are environmentally different to southern Mesopotamia.

The results of the research from these two areas underline the need to obtain and use local data. Throughout the analysis of the data, it became increasingly apparent that environmental conditions and changes were much different to the somewhat accepted scenario of increasing aridity leading to increasing precariousness of farming and increased reliance of irrigation for instance, that is held in the Near East.

Both sites were also useful because as they were both rural sites, as opposed to sites located in urban areas, it was easier to obtain offsite samples, which would give invaluable information regarding environmental change and to address the research aims proposed. Other sites were considered for this project, including Sidon in the Lebanon. Unfortunately, it was not possible to obtain offsite samples (Saida is a very large city), and thus answering questions regarding land use and environmental change would simply not be possible. As discussed in Chapter 5, the evidence from onsite contexts, while useful, is not particularly helpful in looking at environmental questions because the onsite record often reflects what was purposefully brought on to the site. In addition, although we can surmise that what was brought on site could have been grown locally, we do not have absolute proof of this. It is far better to be able to corroborate any conclusion of this type with offsite evidence.

1.4 Structure of the thesis

The structure of the thesis is as follows:

Chapter 2 (Climate and environmental change in the Near East) first gives an overview of climate change and how climate systems work. A discussion on timescales and variability follows.

The role of human agency is then brought into the discussion, and how this may impact the environment and climate systems. Issues with palaeoclimatic evidence and climate proxies in the Near East is then discussed, along with an overview of regional evidence for the so-called '4.2KY event'.

Chapter 3 (The sites) aims to put the sites into context. Each site is discussed separately. Firstly the environmental (geological, geomorphological and climatological) background to both study sites is given. This is followed by an overview of regional context (i.e., how the site fits into the general Near Eastern history) as well as a background to pottery survey and archaeological work done on the site and surrounding regions.

Chapter 4 (Constructing landscapes: environmental change and human agency) introduces the theoretical framework, cultural niche construction, that the research follows. This chapter explains why this particular framework was chosen and how it is useful in understanding the complex relationship between societies and their environments, as well as how it can be used to explain environmental and cultural change.

Chapter 5 (Methodology and methods) firstly discusses the background of both methods used in this research. Both benefits and shortcomings are discussed. In addition, a new protocol for differentiating land surfaces through the understanding of phytolith taphonomy is introduced. The individual methods used in both the sedimentary and phytolith analyses are also spelled out, including laboratory protocols and recording parameters.

Chapter 6 (Results) summarises the results of the research for each site. Hirbemerdon Tepe is discussed first, with geoarchaeological and then phytolith results being presented. This is then followed by the results from Bakr Awa and Shahrizor plain. Both are illustrated with histograms and tables of the results of the various analyses carried out on both the sediments and the phytoliths.

Chapter 7 (Interpretation I: General trends in local environmental change) sets out to answer the first two research questions regarding local-scale environmental change and land use. Although the sites are discussed separately, the different strands of evidence, sedimentary and phytolith, are brought together, along with any other available evidence to firstly understand the environmental history of the alluvial plains and then to understand how the respective societies may have managed three niches: arable, wetland and woodland. This discussion paves the way for Chapter 8.

Chapter 8 (Interpretation II: The cultural niche construction perspective) discusses the third research question regarding the use of sedimentary and phytolith evidence to explain human modification of the environment and ecological and cultural inheritance as posited by cultural niche construction theory. This chapter is structured using the three niches developed in Chapter 7: arable, wetlands and woodlands, and develops models by which the niche constructing activities and subsequent ecological and cultural inheritances can be understood.

And finally, Chapter 9 briefly sums up the research, particularly in terms of why it is important in the understanding of the society/environment relationship. In addition, it outlines future goals, as there is still much to be done.

Chapter 2

Climate and environmental change in the ancient Near East

2.1 Introduction

This chapter will first provide a brief description of the ’global climate system’ (Dunbar 2000), its constituent parts and how these may affect general climate patterns in the Near East. This is followed by a discussion on the role of human impact on climate and environmental change, particularly on the local to regional scale, followed by a discussion of the issues with using palaeoclimatic data to address archaeological questions. Lastly, there is an overview of the climatic and environmental conditions during the period addressed in this thesis, broken down by region.

Climate and environmental change are two distinct processes, albeit two very closely linked ones. Climate change refers to changes within the global climate system. These changes, obviously, will have an effect on the environment, which will be reflected, for instance, in sediments, vegetation and hydrology. These changes will also be differ form region to region as climate change acts differently in different locales. At the same time, changes in the environment, whether natural, anthropogenic or both, can impact the climate, particularly on the local scale.

As will be discussed in the Theory chapter, this thesis follows the basic premise of Earth Systems Science, within the framework of cultural niche construction theory, and considers the different 'spheres' (hydrosphere, geosphere, atmosphere and biosphere) to be interdependent, such that changes in one sphere will affect other spheres (see for instance: Dincauze 2000, Butzer 1982, Hornborg and Crumley 2007). The different spheres will be impacted by both human modification to the environment as well as natural climate variation.

For the purposes of this chapter, more generalised terms such as 'climate change' (encompassing the heliosphere (sun) and atmosphere mainly) and 'environmental change' (encompassing mainly the hydrosphere, geosphere and biosphere) are used, with some reference as to how changes may manifest themselves in the different spheres, such as in discussions of changes to sedimentation and hydrology.

2.2 Climate change, variability and weather

In order to understand climate change, one has to understand climate itself in terms of cycles and mechanisms and their interdependence with each other. There is, for instance, an interplay between the heliosphere and atmosphere. In addition, one also needs to understand how climate change differs from shorter term weather fluctuations, which in turn underlines the need for definitions of timescales as well as terminology.

2.2.1 Timescales and variability

Timescales are important when differentiating between climate change versus variability (Burroughs 2007). Changes are 'shifts in meteorological conditions lasting a few years or longer' and which usually involve more than one parameter (for example, precipitation and temperature) and are global (Burroughs 2007; p. 2), but with local/regional variation. Variability simply refers to variations in weather, which can be significant from year to year, or seasonally, however always remain within the mean ranges (in terms of average temperatures and rainfall, for instance; Burroughs 2007).

Variability may be somewhat predictable and mitigation strategies could be in place. If an area is 'marginal' in terms of precipitation, and drought is a regular occurrence, then different strategies may be pursued, such as irrigation and pastoral economies; these may also contribute and/or exacerbate environmental and microclimate change (see Chapter 4 for further discussion).

When climate change actually occurs, then other questions arise: was the change gradual or more abrupt? At what timescales are terms such as 'abrupt' being used? What impact did this have on the local/regional environment? How was the change perceived by people? And finally, what decisions did people make, if any, in these changing conditions?

2.2.2 Climate systems: definitions

There are many factors, terrestrial and extraterrestrial, that affect climate. These include: oscillations (ocean-atmosphere interactions such as El Niño) and reversals of equatorial wind patterns and other circulation patterns (such as the circumpolar vortex and the intertropical convergence zone (ITCZ)), sometimes referred to as 'global climate systems' (Dunbar 2000, Wanner *et al.* 2008); radiation balance (i.e., the albedo effect, as well as the effect of cloud cover); sea surface temperatures (SSTs); orbital forcing (e.g., Milankovich cycles) and variations in the sun's solar output (Burroughs 2003; 2007, Bradley 2005, Dunbar 2000, Williams *et al.* 2004). Furthermore, because it is a complex system, many of these factors are obviously interconnected, and involve feedback mechanisms, whereby one variable is affected and in turn affects other variables, thus altering substantially the outcomes (Burroughs 2007, Dincauze 2000, Butzer 1982, Williams *et al.* 2004, Wanner *et al.* 2008).

Oscillations

Oscillations are global pressure patterns, which have a 'see-saw' effect: one region will be cooler while another will be warmer (Burroughs 2003; p. 54), and some twenty such systems have been identified (Dunbar 2000); only a few will be discussed here. The North Atlantic Oscillation (NAO) is the measurement of 'the strength of the westerly circulation in mid-latitudes of the northern hemisphere' (Burroughs 2003; p. 54). For example, in a so-called positive phase (in the winter), there is a strong westerly wind that will bring cold air over Greenland and warmer air throughout Europe (Burroughs 2003). However, below 50 degrees north, there is a negative correlation (Burroughs 2003, Roberts *et al.* 2011a, Oldfield and Thompson 2004), meaning that there will be the opposite effect in the Middle East and Mediterranean.

The issue with NAO, unfortunately, is that it is very difficult to discern its effects in the proxy records. Modern records of the NAO go back to 1935, and it has been determined that variations in winter weather are due to the NAO one-third of the time (Burroughs 2003). However, the Greenland ice cores only give annual average data, so winter data (i.e., snow cover and temperatures) are lost (Burroughs 2003).

The Southern Oscillation is closely associated with El Niño, and as such is now known as the El Niño Southern Oscillation, or ENSO (Burroughs 2003). ENSO affects trade winds, rainfall and sea surface temperatures (SSTs, which in turn affect storm patterns) and impacts weather systems globally (Burroughs 2003, Dunbar 2000). There will be some knock-on effect in the Middle East, however, this may be difficult to discern in the proxy records. In addition, there is evidence that ENSO became a more prominent climate system after the Mid-Holocene (ENSO may not have existed before 5000 years ago: Dunbar 2000, Donders *et al.* 2008).

There are many other oscillations and include the Atlantic Multidecadal Oscillation (which may be related to the NAO), the North Pacific Oscillation (NPO) and the Interdecadal Pacific Oscillation (IPO) (Burroughs 2003, Dunbar 2000). Stratospheric winds may also cause oscillations, for instance, the Quasi-biennial Oscillation (QBO). In essence, the westerlies and easterlies interchange every two years or so in the upper atmosphere. The impact of this on other oscillations is not understood (Burroughs 2003). There may also be a relationship between the QBO and sunspots (Burroughs 2003).

Many of these oscillations seemingly take place in areas geographically distant from the Middle East, however, they still have an impact on the local and regional climate, especially with regards to rainfall patterns (Dunbar 2000). Unfortunately, many of these effects are difficult, if not impossible, to detect in the proxy records.

Sea surface temperatures

Although the study areas are inland continental, sea surface temperatures (SSTs) may still impact local climate patterns. There are ocean-atmosphere feedback mechanisms in that if SSTs change, this will affect atmospheric conditions (i.e., weather) and when the atmosphere is affected, this will in turn impact SSTs and so on (Burroughs 2003; 2007). This is particularly evident when discussing oscillations such as ENSO, where warmer SSTs leads to the increase of storms, which can in turn affect precipitation patterns across a wider geographical area.

Circulation patterns

The main hemispheric circulation pattern is the Circumpolar Vortex, where more solar energy is drawn in at the equator and expelled at higher latitudes (Burroughs 2003). In essence this then affects the position of the jet stream: areas above the jet stream will be cooler (impacted by polar climate) while areas below it are warmer.

However, the circulation pattern most relevant to the study area is the Intertropical Convergence Zone (ITCZ), which is essentially a band of 'rising air, cloudiness and high rainfall' (Burroughs 2003; p. 144; see Figure 2.1), which is currently situated near the equator and moves up and down with the seasons, thus affecting weather (seasonal) systems. The ITCZ marks the zone where the southern and northerly trade winds meet (Dunbar 2000). Above and below the ITCZ are Hadley cells, which are circulation patterns: heated up moist air rises up from the clouds to form clouds, the heat is released and the moist air moves up, is precipitated out and moves towards the 20 degree latitude; the cold, dry air descends down again, creating the desert region, and moves towards the equator where it starts the cycle again (Burroughs 2003; 2007). More solar energy is absorbed at lower latitudes, which is then circulated to the upper latitudes (Burroughs 2007).

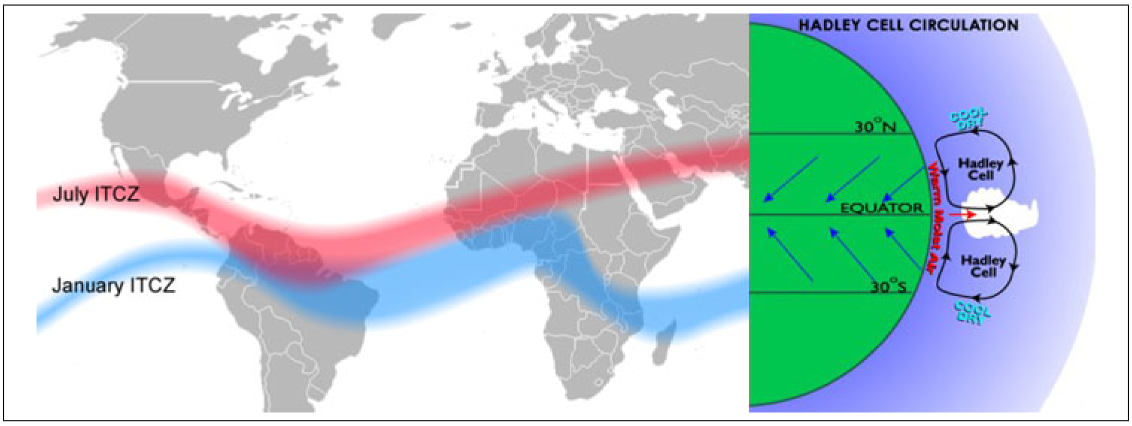

Figure 2.1: Approximate modern position of the ITCZ in the summer and winter, with schematic drawing of Hadley cell circulation. Modified from: Halldin (2006) (ITCZ) and Satterfield (2011) (Hadley cells)

Radiation balance

This is the amount of solar energy that is absorbed and reflected, and is dependent on the 'absorption, reflection and scattering properties of the atmosphere and the surface' (Burroughs 2003; p. 131). In other words, the atmosphere absorbs and scatters a certain amount of radiation, and the surface of the earth also reflects and absorbs a certain amount of energy (Burroughs 2007). The main process is the Albedo effect, which is the amount of energy that is reflected back. Lighter areas, such as the polar and desert regions reflect energy, while darker areas, such as dense forests and oceans, absorb more energy (Burroughs 2003; p. 132; see Figure 2.2).

How energy is absorbed by land and oceans also differs: on land surface, heat is absorbed closer to the surface, and thus more energy is emitted, while in oceans, energy is absorbed at deeper levels, and thus less energy is emitted (Burroughs 2007). Terrestrial radiation, which is the energy from the surface and atmosphere, is dependent on trace constituents in the atmosphere which absorb and re-emit energy, the so-called 'Greenhouse effect' (Burroughs 2007), will also affect the radiation balance. All of this is dependent on cloud cover, which also has an albedo effect, and which will reflect a certain amount of solar energy back (Burroughs 2007).

Solar radiation is affected by the tilt of the planet, as well as the amount of radiation output (which is not a constant) by the sun (Burroughs 2003). Solar radiation affects the stratospheric winds, which in turns affects the climate

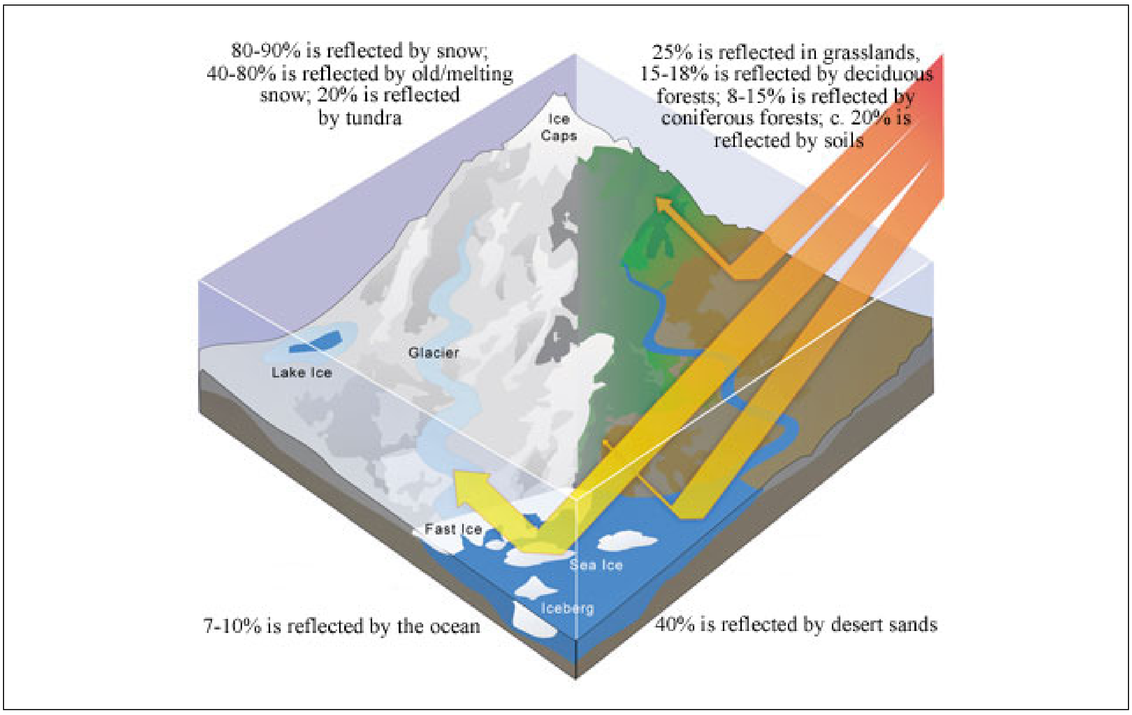

Figure 2.2: Figure illustrating different reflectivity of solar energy depending on ground cover. Image modified from Anonymous (2009); albedo data from climatedata.info (2010)

(Bradley 2005). The radiation output of the sun also seems to run with some periodicity, for example sunspots, which are associated with solar winds and the solar magnetic field, increased output and which have a cycle of about 11.2 years (Burroughs 2003; 2007). The solar magnetic field affects the output of solar energy and thus will affect Earth's weather as well (Burroughs 2003).

Gravitational pull from other planetary bodies can also impact the orbit of the Earth, and thus the amount of radiation from the sun and climate patterns (Burroughs 2003; 2007). Furthermore, the Earth's orbit also follows different periodicities, which also impact the radiation balance and climate patterns (Burroughs 2003; 2007). This known as orbital forcing, i.e., the Milankovich Effect, and helps to explain periods of glaciation.

Monsoons

The monsoons (summer rainy seasons) are impacted by the position of the ITCZ, where in the northern hemisphere in the summer months, the ITCZ is further north, and leads to the 'sustained expansion' of the Indian monsoon (Burroughs 2007; p. 37). This in turn, impacts the zone immediately north, which consists mainly of continental deserts and above this, the Ferrel cells or westerlies, which push circulation towards the pole (Burroughs 2007). Both sites are located within this latter area. ENSO will also impact the Indian and Asian monsoons: during an ENSO event, the ITCZ is shifted further south, and there may also be similar effects in more northerly latitudes, but this is not very well understood (Burroughs 2007).

The ITCZ has been shifting up and down in the northern hemisphere throughout the Holocene, first moving more northerly, and currently (since the Mid- to Late Holocene) more southerly (see Figure 2.3), which has resulted in the expansion of the Sahara and changes in hydrology across the Near East (Scheffer 2009, Fleitmann *et al.* 2007, Roberts *et al.* 2011a, Tzedakis 2007) and decreasing seasonality in the northern hemisphere (Haug *et al.* 2001).

The shifting of the ITCZ has knock-on effects, for instance, the weakening of the Asian and Indian monsoons (summer rainy periods), which in turn affect summer precipitation patterns across the Middle East (much of the annual precipitation now falls in the winter months). There is a debate on whether the decreased summer monsoonal precipitation was abrupt or gradual in the Mid- to Late Holocene (see Fleitmann *et al.* 2007, Roberts *et al.* 2011a). Again, it is important to understand what timescales are being used to address these issues of 'abrupt' versus 'gradual' decreased precipitation.

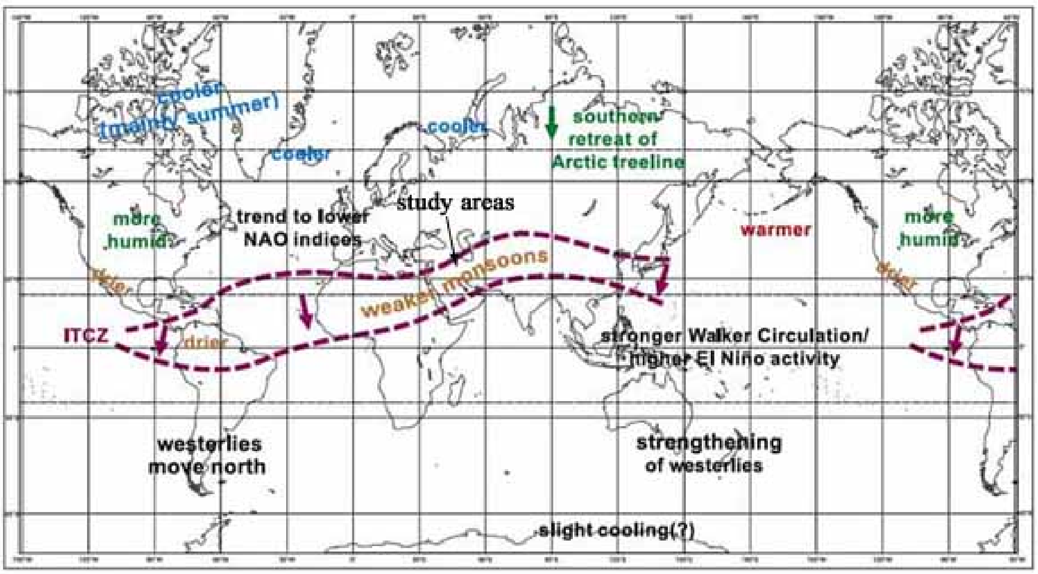

Figure 2.3: Since the Mid-Holocene, the ITCZ has been shifting southwards, thus affecting weather and climate patterns globally. Map modified from Wanner *et al.* (2008), p. 20, Fig. 18

2.3 Climate change and human agency

As stated above, there are many different climate systems, and although their activity seems to be centred elsewhere, for example, in the Pacific area, they do have an impact in a wider area, including the Near East, throughout the Holocene (Dunbar 2000). The impact is mainly in terms of the amount of annual and seasonal precipitation, which can sometimes have a negative impact, such as drought and/or flash flooding (Dunbar 2000). As discussed above, the different parts of the climate system are interlinked and interdependent, so that if there is a change in one aspect, there will be changes in the others – these are climatic feedback mechanisms (Burroughs 2003; 2007).

Climate change, or least variability, can be related to a variety of causes, including: changes in the atmosphere (ENSO; rainfall), solar output, volcanic eruptions (and volcanic aerosols), Milankovich (orbital forcing) effect, as well as natural and human induced changes in atmospheric gas variability (such as methane, CO2) (Dunbar 2000).

Dunbar (Dunbar 2000) states that often the temperature changes caused by any climate change is only a matter of a few degrees and may not have a huge impact on societies; however, it is the change to local precipitation patterns and hydrology that can cause problems for particular societies, especially those in more arid areas. And these changes can be magnified by both human modification of the environment as well as natural climate change. This is discussed more in detail in Chapter 4.

Here we turn to another variable which has been hinted at but not discussed in detail: humans and their impact on the environment and global climate systems.

2.3.1 Human impact on climate and environmental change

Natural climate change and human induced change can be difficult to disentangle from the Mid-Holocene onwards due to the increasing impact by humans (Roberts *et al.* 2011b) in terms of deforestation, increasing agriculture and pasturage, and urbanisation. This is a particular problem in the Near East, where agriculture (and its associated increasing deforestation and pasturage) begins early in the Holocene. Most of the possible impacts discussed here will be those relevant to the time period of this thesis and thus modern issues of 0_3 (ozone) particulates and other modern pollutants will not be discussed.

The main impact is the acceleration of processes. Human activities, such as deforestation, agriculture and grazing, can amplify the effects that climate change has on a local area, especially in areas where there is lower annual precipitation. This can also, in turn, affect local climate patterns, such as decrease precipitation further, the causing a further acceleration in processes.

Deforestation is an activity, which has huge implications for microclimates, river hydrology and local / regional vegetation. Trees and other vegetation on slopes play a vital role in the hydrological balance of an alluvial environment. There is a delicate balance between vegetation, sediment yield and discharge in a river system. Trees and other vegetation collect the water from precipitation, and it is released back into the atmosphere via the evapotranspiration process; some water seeps into the soils and sediments and is percolated downwards (Giller and Malmqvist 2008; see Figure 2.4). If the soils become saturated, then some of the water will enter the stream system via overland flow. This saturation and overland flow is regulated by the vegetation as well, in that roots increase the porosity of soils and sediments, thus more water will percolate downwards (Giller and Malmqvist 2008). Soils and sediments are also less prone to erosion because of the presence of vegetation and roots, which holds soils in place.

This relationship between precipitation, evapotranspiration and vegetation helps to regulate stream flow and sediment yield and so the flow tends to be more consistent (Giller and Malmqvist 2008). If the foothills and mountains are denuded of tree cover, this will have a negative impact on the hydrological system: seasonal discharge magnitude may increase, causing flash flooding, sediment yield increases (from slope erosion), riverbeds may dry up during the dry season and many springs will also dry up.

In addition, trees' evapotranspiration process adds moisture into the atmosphere and is an integral part of the precipitation process. In the case of defor-

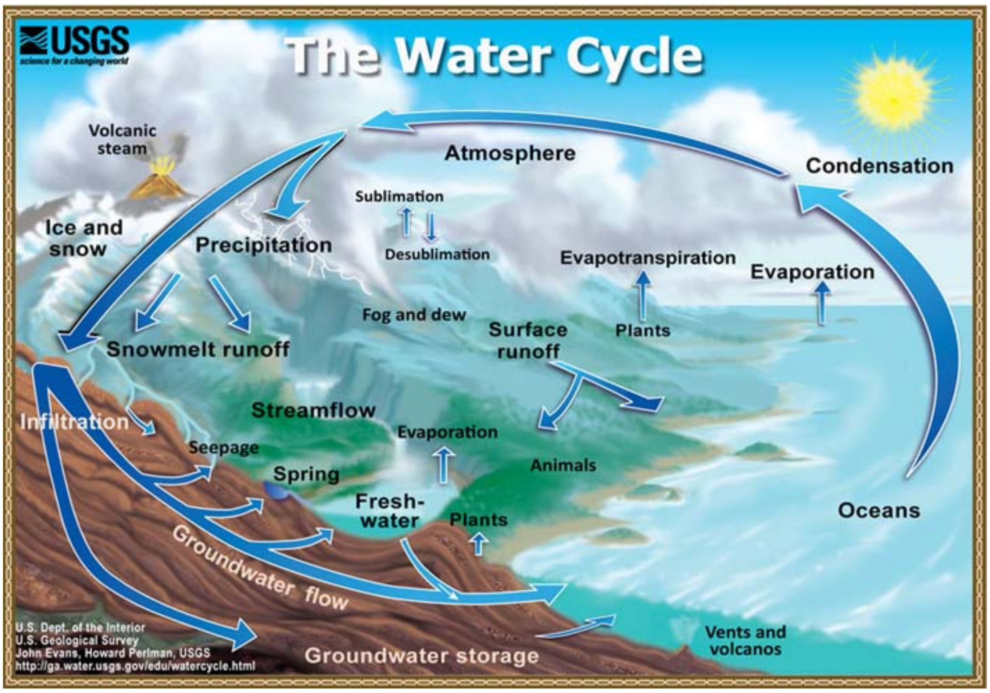

Figure 2.4: Illustration of the hydrological cycle. Source: USGS (2014)

estation, this feedback process then means that there is less moisture available, thus accelerating the local levels of aridity. This, too, impacts hydrology, sedimentation and vegetation.

Dust particulates that enter the atmosphere can reflect heat back out, and thus cause a cooling effect on the surface (Burroughs 2007). Dust particulates may be natural in origin (dust storms and the like) but could be magnified by human impact. Increasing agriculture, for instance, can create more areas which have little or no vegetation and thus are more prone to aeolian erosion and dust storms. In addition, if there is also less precipitation, there may be an increase in devegetated land, with an increased risk of dust storms.

Human impact can also have an effect on albedo, which in turn has an effect on the climate. For instance, devegetation of an area can lead to decreasing albedo, whereby heat is absorbed by the brown (darker) land surface (see Figure 2.2). This can lead to desertification, which in turn increases the albedo effect, which leads to cooling and decreased evapotranspiration (of plants), which leads to decreased amounts of water vapour and clouds (Burroughs 2007); i.e., less rainfall. So in other words, if there is increasing aridity and an increase in human activity, such as deforestation, this can lead to the acceleration of the effects of aridification.

The acceleration of climate and environmental change, through human modification of the environment, has wide and varying implications for the sustainability of resources, societies and environments, especially in so-called 'marginal' areas, but also in more environmentally resilient areas such as the study areas discussed in this thesis.

2.4 Issues with palaeoclimatic data and archaeological questions

Climate and environmental change, both natural and anthropogenically influenced, have been studied and written about extensively, particularly in relation to how climate and environmental change may have impacted societies in different periods. In some cases, climate change has been used to explain 'collapse', for example, the fall of the House of Akkad (see for instance Weiss *et al.* 1993, Weiss 2012a). There have, of course, been arguments against this monocausal approach (McAnany and Yoffee 2010, Kuzucuoğlu and Marro 2007, Rosen 2007; to cite but a few).

And while much research is much more sophisticated than the monocausal environmental deterministic approach, with an understanding that societal issues, local changes and resilience of the environment are all very important variables, there still remains a big problem: palaeoclimatic / palaeoenvironmental data is not being used correctly to address archaeological questions. There are two main issues: date correlation and using macro-scale data to answer micro- to meso-scale research questions.

This section will first describe some of the proxy evidence used in Near Eastern palaeoenvironmental / palaeoclimatic reconstruction, and then will address the issues of dating and scale.

2.4.1 Climate proxies in the Near East

In reconstructing past climates in the Near East, there is limited data. Most evidence comes from proxy records, including: sediments, ice cores and microfossils (phytoliths, diatoms, foraminifera, pollen, etc), also faunal and macrobotanical remains and speleothems. However, many of these are indirect indicators and can be ambiguous.

Furthermore, some of the effects on the environment may not show up in some proxy records until much later after the 'event', if at all (Burroughs 2007). This is known as 'lag time' – certain assemblages, plants for instance, may continue to persist despite changing climatic conditions, and indeed may continue to do so unless there is some additional external input (usually anthropogenic), which leads to the decline in population (Scheffer 2009). It is at this point that evidence for climate/environmental change may show in the proxy record.

Many researchers (see for example, Roberts 1998, Roberts *et al.* 2001, Rosen 2007, O'Brien *et al.* 2005) advocate a multiproxy approach which can add further detail and add robustness to the interpretation. Specifically, this means carrying out different analyses (sediment, phytolith, diatom, isotope) on samples from the same context.

In addition, when interpreting any type of on-site environmental evidence, be it macrobotanical, faunal remains, phytoliths, etc, it is necessary to bear in mind that what is there may not be representative of climate / environment, but rather of choice, trade, religious practice, and so on.

Speleothems, ice cores and isotopes

Isotope analysis (oxygen and carbon) is often used in palaeoclimate studies. Oxygen isotope ratios (O^{18} to O^{16}) have been used to measure past temperatures (Roberts 1998). Speleothems (stalagmites collected from karstic caves), using oxygen isotopes, have been used successfully to measure past precipitation patterns (Rosen 2007, Bar-Matthews *et al.* 2003; 1999, Burroughs 2007, Fleitmann *et al.* 2007), as well as available moisture using carbon isotopes (Göktürk *et al.* 2011).

Speleothems extracted from cave systems where there is no outside interfer-

Figure 2.5: Prof. David Mattey (Royal Holloway) collecting water samples in Kuna Ba cave, Suleimaniyah province

ence (i.e., shafts which permit contamination from modern elements) provide very good baseline climate information on a local and smaller regional scale. This baseline data can then be compared with other environmental proxies, such as sediments, pollen and phytoliths, to better understand the nature of the regional and localised climate / environmental change, and human environmental modification.

Dating of speleothems is done through uranium dating and can give very precise, accurate dates. For instance, Sofular cave speleothem So-1 has a resolution of about 5.4 years (Göktürk *et al.* 2011). Unfortunately, no speleothem studies have been done in the Hirbemerdon Tepe area, and cave monitoring work has only just begun in the Shahrizor region (see Figure 2.5), although some initial analysis has been done on a couple of speleothems (see Chapter 6).

Ice cores, too, have been used to gauge temperature, atmospheric dust and snow fall, as well as volcanic activity (Burroughs 2007, Stuiver and Grootes 2000, Steig 2008). However, ice cores are recording general global or hemispheric changes, rather than specific localised shifts in temperatures (see for instance, Stuiver and Grootes 2000, Vinther *et al.* 2006), and for recording long-term climate patterns (Steig 2008), and there are issues relating to timescale, sampling and spatial uncertainties, particularly when looking at shorter timescales, i.e., less than millennial (Steig 2008).

Deep sea cores are used in similar way, and measure the ratios of O^{18} and O^{16}, again giving climate information at a global or larger regional level (see for example, Cullen *et al.* 2000). Interpretation of this type of data may be problematic as well.

Pollen

Palynology is widely used in palaeo-reconstructions, but there are issues in using this evidence especially with regards to the fidelity of the fossil assemblage (a problem which is prevalent in all microfossil analyses: see Brenchley and Harper 1998). Biases can occur because of the mechanisms of pollen dispersal (i.e., by wind, water, insect), whereby some pollen is dispersed far and wide and some stays close to the source (Roberts 1998, Rosen 2007). Some plants also pollinate more than others so may dominate the record. Biases can also emerge because of differential preservation (Roberts 1998).

There are also other issues, for instance, the use of uncalibrated carbon-14 dates (see below) and the time lag effect (Rosen 2007, Wick *et al.* 2003, Scheffer 2009), as discussed above. Pollen analysis is usually carried out on lake core sediments. For the Near East, there are only a few studies (e.g., Lake Van, Mirabad and Zeribar), which are often used in discussions about environmental change. The problem is that while these studies are robust, the vegetation patterns in the cores reflect more localised and semi-regional patterns, and may not be applicable to all areas (see below).

Diatoms

Diatoms are microscopic unicellular algae made up of biogenic silica (similar to silica phytoliths) and are very useful in climate and environmental studies. They are normally studied in lake core sediments and because they are particular in terms of where they live, can give information on changes in temperatures, pH, salinity, turbidity, water depth and pollution, particularly agricultural pollution (Battarbee 1986, Lowe and Walker 1997, Juggins *et al.* 1994).

Regional diatom studies have been carried out on the Zeribar core (Snyder *et al.* 2001).

As with pollen analysis, however, lag time is also an issue – there will be an interval between climate and environmental change and the reaction in the diatom community, particularly if the change is gradual and initially has little effect on the algae due to their ecological tolerance ranges. Ecological communities do not change overnight, and sometimes may not change much, even with climate or environmental change, because there is a certain tolerance level before a system reaches its threshold and tips into another state (in this case is replaced by a different community of diatoms). Furthermore, there is the usual problem of preservation of the assemblage.

Sediments

Sediments, especially those deposited in basins or alluvial plains via river or aeolian processes, can give valuable information regarding localised and semi-regional climate and environmental change. Through the analysis of facies as well as laboratory methods, aggradation patterns, energy levels of the river, flash flooding episodes, channel switching and breaks in deposition (due to a river incising into the alluvial terrace) can be discerned. These patterns are a reflection of a river's changing hydrology which is an indirect record of changing climatic and environmental conditions. However, it should also be noted that river behaviour is influenced by human activity, particularly deforestation, which affects the water budget cycle and therefore the hydrology (see above). For this reason, analysis of sediments should also be combined with other proxy evidence. Sediments are discussed more fully in Chapter 5.

Phytoliths

As discussed in Chapter 5, phytoliths are usually used in onsite archaeological studies to understand diet, processing, storage and agricultural behaviours. In this thesis, phytolith analysis has been extended to include offsite samples to gauge the level of vegetation change and to locate possible land surfaces and agricultural fields. As with sedimentary evidence, the phytolith data should be used in conjunction with other datasets; and in addition, phytoliths found in alluvial contexts may either have been deposited *in situ* or derived from elsewhere, and ideally, these should be differentiated (see Chapter 5).

2.4.2 Dating issues: AMS/C14 versus typological

Robustness of dating is an issue in palaeo-reconstructions, not just in terms of the number of dates but also in the calibration of BP dates. There are date gaps in the record and the available dates are not always robust (Burroughs 2007). AMS (accelerated mass spectrometry) carbon-14 dates, while very useful, can have date ranges of decades to centuries, which can then impact any interpretations when applied to human societies. Long date ranges are acceptable in discussions on how climate/environmental change may have affected a certain region over a longer period of time. However, when one wants to make statements regarding impact on and modification by a particular society, one has to make sure that the dates do indeed correlate.

The issue is further complicated through the use of uncalibrated carbon-14 dates (especially older C14 dates): these can be off by 600 years (Roberts 1998) and can be impacted by the reservoir effect which can make the dated material appear older than it really is. This makes correlating C14 palaeoenvironmental dates with archaeological dates even more difficult. Uncalibrated dates can be calibrated (there are software programs such as OxCal, which use dendrochronology to calibrate carbon-14 dates), and Roberts (1998) advocates using calibrated BP dates, while Kuzucuoğlu (2007) advocates using calibrated BC/AD dates. It should be noted that the uncalibrated issue only concerns C14 dates, not BP dates derived from thermoluminescence, uranium series or other dating methods (Kuzucuoğlu 2007).

One also has to distinguish between the 'accuracy' and 'precision' of the dating methods (Walker 2005, Weiner 2010). Accuracy relates to the 'bias' in the way an age is measured by a particular instrument, the difference between the measured age and the true age (Walker 2005; pp. 5-6). Precision, a concept that is more pertinent to this study, refers to the level of 'statistical uncertainty' for a given date (Walker 2005; p. 6). This uncertainty is usually reflected as a date range, with 1σ (68 per cent probability, 30 year range)and 2σ (95 per cent probability, 60 year range) confidence level (Weiner 2010).

It may be possible to obtain much more refined results, but this requires the analysis of far more samples, and by extension requires much more money: one would need four times the number of samples in order to double the accuracy (Weiner 2010). At Tell Leilan, Weiss (2012c; 2008) has been able to more precisely date post-Akkadian layers and showed how the site, although still occupied, had contracted. This was done by subdividing samples into two or three aliquots to obtain more dates, which were then averaged out (Weiss 2012c; 2008). The problem with this is that because it costs a great deal of money, one has to make a choice between very precise samples, taken from a few samples, or less precise samples taken from more samples (see also Weiner 2010).

There are chronological issues too, within Near Eastern archaeology, which can also affect the correlation between cultural events and climate/environmental change. There are two concerns which affect chronology of the second millennium (and by extension late third millennium chronology). According to Bietak and Hoflmayer (2007), these include different levels of chronologies and historical dates versus carbon-14 date correlation. In the Near East, four different chronologies have been adopted: ultra low, low, middle and high.

Typological dates and C14 dates from the same sites are often also out of synch, with disparity often in the region of one to two centuries (Roberts *et al.* 2011a). As Bruins (2001) points out, environmental archaeologists often use C14 dating, whereas archaeological dating is still restricted to ceramic typologies (i.e., cultural periods), and it can be difficult to correlate these two types of dating methodologies. Bruins (2001) further says that much more work needs to be done in the Near East in terms of dating the fourth to third millennia, because many of the periods are actually older according to C14 dates in relation to the cultural dates. In addition, C14 dates, from the 15th century BC going backwards are out of synch with Egyptian historical dates by 100+ years; although some of the problems may lie within the historical dates as well: different scholars give different dates for the same Egyptian dynasties, which can be 100 years or so apart (Bruins 2001). Furthermore, much of the dating in the region is still reliant on ceramic typology, and is often not independently corroborated (Bruins 2001).

And finally, the dating of many periods is still unknown, especially 'cultural transition' periods between the EBA into the MBA, which can be out by anywhere from 50 to 100 years (Roberts *et al.* 2011a). Basically these issues lead to confusion in terms of tying events together, either spatially across the region, or temporally (i.e., correlating the so-called 4.2KY event with societal collapse).

A third issue is different regions have different chronologies, based on different typologies, i.e., there are chronologies for the Levant, Anatolia, Mesopotamia and Egypt, which do not always correspond with each other. So what is considered Early Bronze Age in one region is not necessarily equal (although may be close to) the Early Bronze Age in another region (see Figure 2.6).

2.4.3 Spatial and temporal scales

When discussing climate and environmental change in the context of southeast Anatolia and Iraqi Kurdistan (and indeed other regions in the Near East), one needs to consider scales, both temporal and spatial.

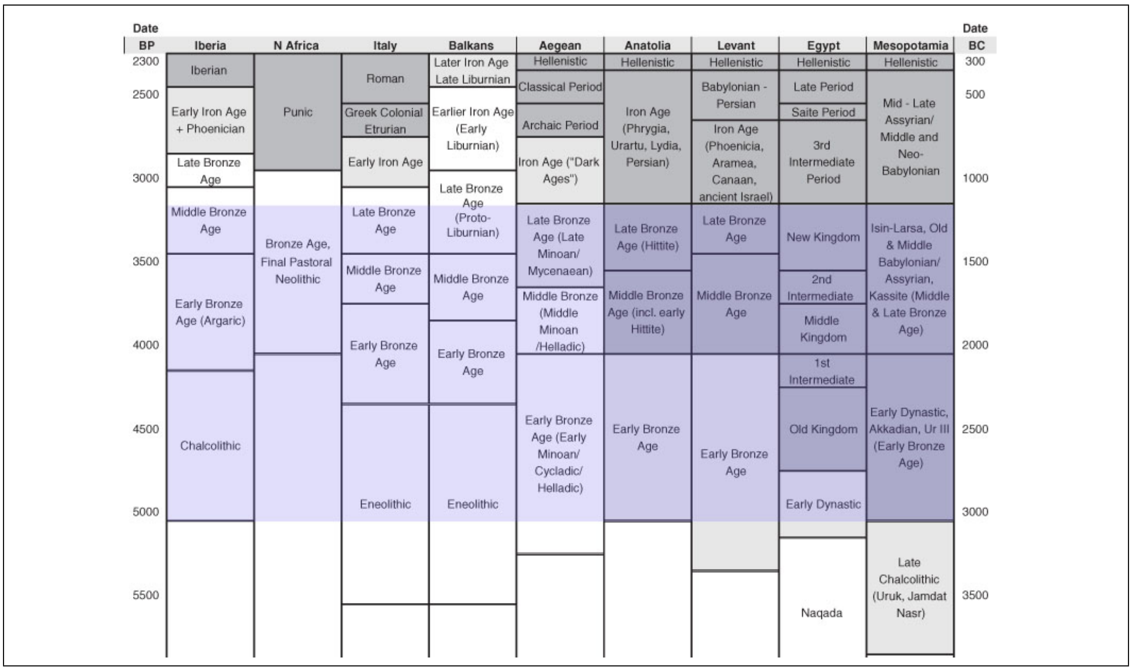

Figure 2.6: The chronological periods for different parts of the Near East from the Chalcolithic onwards. The blue shaded area indicates the approximate time period covered in this thesis. Modified from Roberts *et al.* (2011b), p. 151, Fig. 3

Timescales are also important when attempting to correlate social change and palaeoenvironmental data. The resolution of the palaeoenvironmental data is still rather coarse, and may be indicating longer-term processes (Bailey 1981) and the shorter-term human events, for example, social change and agricultural strategies, may not be reflecting these longer term climatic/environmental trends. This runs into the danger of associating one set of phenomena with another, and they may not be connected. As such, the adaptations that are seen in the archaeological data may be reflecting short-term variations (between seasons and years) rather than longer-term climate change. In fact, these human activities may not be 'adaptations' but rather modifying behaviours that may cause or at least accelerate environmental change.

And even when considering general global or hemispheric change, perhaps increasing aridity due to changing climatic parameters, it needs to be understood that how this is reflected 'on the ground' will differ across a region, i.e., localised effects. These will be dependent on local variables such as altitude/terrain, hydrology/water availability, vegetation and of course, human modification.

Local versus general trends

There is general agreement that an aridification trend occurs across the Eastern Mediterranean after about 5000 years ago, although this too varies from region to region (Roberts 1998, Roberts *et al.* 2011b, Rosen 2007). Different factors contributed to this trend, including orbital forcing (Kutzbach and Street-Perrott 1985). This trend was occurring in southeast Anatolia and Iraqi Kurdistan as well. There are a number of factors that would have impacted the climate regime of southeast Anatolia and Iraqi Kurdistan at this time, including the position of the ITCZ (see Figure 2.3) and the intensity of the Africa/Asian monsoons, and the effects of orbital forcing (July insolation has been decreasing in the northern hemisphere since the onset of the Holocene, thus decreasing seasonality: Bradley 2005, Kutzbach and Street-Perrott 1985, Wanner *et al.* 2008).

The ITCZ has been shifting downwards (southwards) and this in turn has been affecting (weakening) the monsoons (African and Asian) leading to increasing aridity (Wanner *et al.* 2008). In addition, the circumpolar vortex may have contributed to shorter-term variability (Macklin *et al.* 1995, Winstanley 1973): as its wave pattern and strength shifts year on year, the northern hemisphere experiences cooler and warmer winters. This is not uniform across the hemisphere, however, while one area may have a warm winter, another will experience cooler conditions. The North Atlantic Oscillation (NAO) probably had minimal effect in this region (Frumkin 2009, Jalut *et al.* 2009), and so will not be considered a factor.

There has been much discussion regarding the so-called 4.2KY event, and it needs to be ascertained whether it was an abrupt and short term change, i.e. a 'rapid climate change' (RCC) event (Bar-Matthews and Ayalon 2011, Weiss 2012a) or something that was more gradual and long term (Rosen 2007, Roberts *et al.* 2011b). The problem is that evidence for abrupt changes in the Holocene is sparse (Dunbar 2000) and is reliant on peaks in certain proxy records, especially ice and deep sea cores. Some of the peaks or spikes are seen in some records at around the same time as others, other records do not show any of the spikes. This may be a reflection of how different areas may have reacted differently (Riehl *et al.* 2009). As Jalut *et al.* (2009; p. 13) succinctly point out: '[w]ith respect to the chronology of the main global events, there is a diversity of responses and minor chronological gaps, which could be due to the various regional impacts of the global events, to the time of response of the ecosystems and finally, but not last in importance, to the relative uncertainty of the dating.'

Resolution of the various proxy datasets is limited (Riehl *et al.* 2009). Lake sediment analyses (stable isotope and pollen analyses) undertaken across the region, and even within the same area (i.e., Northern Mesopotamia) have differing results, often because of dating issues (usually there are not enough absolute dates within the samples: Riehl *et al.* 2009). So trying to tie in climate events to social collapse (or indeed change of any sort) is problematic (Kukla *et al.* 1997; and see below).

What is meant by 'abrupt' also needs to be queried: what timescale is being used to measure 'abruptness' of change? Climate change assessed over a centennial or more scale may appear 'abrupt', however, taken over a higher resolution, i.e., over years or decades, may appear more gradual, especially to the societies actually experiencing it (see also McMahon 2012).

Weiss (2012c), for instance, uses proxy evidence from around the Middle East region to show that a widespread aridification 'event' (which he now calls the '4.2-3.9KY event') took place, and this led to the 'adaptive dry-farming Khabur Plains abandonment' (p. 187). It is not debated whether or not new adaptive strategies may have been adopted because dry farming was no longer sustainable in some areas of the Khabur (and elsewhere in the Near East). The problem lies in his use of coarse scale data: he talks of an 'abrupt' event, which took place over 250 to 300 years, which led to a 20 to 50 per cent drop in precipitation (Weiss 2012c). Basically, the data he uses shows that in some regions across the world, there are peaks in aridity, which take place at different times over a 300-year period (Weiss 2012c; p. 187, Figure 26). What this indicates is not necessarily that there a widespread global synchronous abrupt event, but rather that as the climate became generally more arid, some areas had stronger 'reactions', due to different variables. Furthermore, a 20 per cent drop in precipitation over a three hundred year period may not be noticed in a generation or two in an area with higher rainfall, and would certainly not be considered an 'abrupt' event.

Herein lies the problem with the interpretation and focus of much of the palaeo-environmental studies: the application of the incorrect temporal or spatial scale or data to the wrong type of research question. One issue is the correlation of archaeological data from one region to the environmental / climate data from another region. For instance, using Soreq cave data, which is derived from the Levant, to help explain cultural / political change in southeast Anatolia. Soreq cave data pertains to that region of the Levant, and while there may be similar data from other parts of the Near East, i.e., some agreement of general trends, it isn't the right data to use. Soreq cave data measures the change in that local region, which is very dry, and is dependent on the local variations. It may not be applicable to wetter areas in Anatolia, for instance.

In order to understand climate / environmental change in southeast Anatolia and possible repercussions on societal change, local climate / environmental data is needed. And, as discussed more fully in Chapter 4, human modification of the environment also needs to be considered.

Another issue is the correlation of proxy records to archaeological data itself. Archaeological dates come from texts (in a few lucky cases), ceramic typology and sometimes a few C14 dates. As pointed out by Roberts *et al.* (2011b), C14 dates and typology do not always agree and can be out by 100 or more years. In addition to this, proxy dates are often at larger scales – centennial or more – and it is not really possible to correlate centennial ’abrupt’ changes to cultural change (which is usually on a shorter, decadal scale), which may or may not have occurred at sort of the same time (see also Roberts *et al.* 2011b, McMahon 2012). While there may be hints of mitigation through time, unless there is unequivocal data that links a particular climate event occurring just before cultural change (both dated using the same scale), ideas that climate event A ’caused’ cultural change B cannot be proven. Even with this data, sociopolitical evidence needs to be considered as well, because it is the decisions that are made, whether or not as a response to climate change event A, which will determine the sustainability of that particular site, along with the network of trade and the resilience of the surrounding environment. And it may be precisely these decisions that led to environmental change, or at least contributed to it.

In addition, the synchroneity of the proxy data also needs to be queried. Because dating is often limited to AMS C14, date ranges tend to be broad and scientists often try to correlate different datasets with each other through ’wiggle matching’, which may cause what are asynchronous events seem synchronous (Blaauw 2012).

There is much emphasis on trying to correlate particular records with regional or global trends discerned in other proxy records. This is fine when dealing with large scale questions of climatic change on a centennial or longer basis, which can be linked to large scale changes in the global climate system, such as orbital forcing, the gradual movement southwards of the ITCZ and so on. However, the scale must be drastically fine tuned, i.e., to the decadal level, when dealing with people’s perception of change and strategies, especially when trying to relate these with climate and vegetation change. Although these more generalised trends are important, after all, increased insolation can lead to a gradual increase in temperatures, and eventually to a tipping point for some ecological systems, these changes are just that – gradual and long term.

When discussing the issues on a human level scale, firstly localised impact needs to be considered, and then secondly, how people perceived and perhaps caused these changes and thirdly, the natural resilience of the local environment. This is discussed in more detail in Chapter 4, but for now briefly, it is important to factor in local proxy records, rather than regional ones, when trying to assess climate / environmental change and the possible impact this may have had on a given settlement in a given area as well as the possible effects human activities had on the local environment and microclimates.

2.5 Regional evidence for the '4.2KY event'

Many of the dates given in various articles discussed in this section only give calibrated (and sometimes uncalibrated) BP dates. Approximate BC dates are given in parentheses, and are taken from Figure 2.6.

The IPCC working group (Jansen *et al.* 2007; p. 464) found that there were some dramatic climate events occurring between 5000 and 4000BP (*circa* 3000-2000BC), including sea expansion in the northern hemisphere, 'abrupt cooling events' in Europe and a North American drought lasting for many years, however, there is no mention of aridification or a 4.2KY (*circa* 2200BC) event for the Near Eastern region, which is puzzling. Furthermore, Wanner *et al.* (2008), after having collated various proxy databases and entering them into their time-series analysis could find no evidence of any dramatic shifts in climate around this time period. They found that there was general aridification due to the southward movement of the ITCZ after 5500 BP (*circa* 3500BC); this trend was maybe more abrupt in certain regions such as Lake Chad and Mexico; there is no mention of the Near East (Wanner *et al.* 2008).

Burroughs (2007) has a completely different take: he mentions that the cooling events and decreasing precipitation in the Near East could be linked possibly to a 1500-year North Atlantic climate cycle or even to the volcanic eruption detected in Greenland ice cores which date to 2354 BC (possibly Hekla in Iceland), although the latter would surely be more short-term climate change. The link to Bond cycles seems to have some consensus within the palaeoclimatic community working in the Near East Bar-Matthews and Ayalon (2011), Roberts *et al.* (2011b), Bond *et al.* (2001).

Regionally speaking, there seem to be variations in terms of the magnitude of the event and evidence of aridification at the end of the third millennium within the proxy records. As Riehl *et al.* (2009; p. 158) point out, in order to fully understand and appreciate the complexities of the 'palaeogeography' in the region (Upper Mesopotamia in this specific case), 'careful analysis of *local* sources of palaeoenvironmental information in the region' is needed (italics mine). Upper Mesopotamia, for instance, is a mountainous region, and this will affect precipitation patterns, leading to varying climate regimes, which in turn may lead to different vegetation patterns (Riehl *et al.* 2009). These differences may have also led to variable impacts of climate change in the region.

In addition, there is limited site-specific environmental data for the upper Mesopotamian region indicating farming practices, and so the impact of climate change on human economies is debatable (Riehl *et al.* 2009). As Kuzucuoğlu (2007) points out, changes are indicated by various proxy records, but whether these reflect local or global 'natural' events and/or human modification still needs to be determined.

2.5.1 Anatolia

Evidence from several stalagmites from cave sites in Turkey (Kocain cave, southern Turkey; Uzuntarla and Sofular caves in northwest Turkey) all indicate similar general trends, such as an increase in wetness previous to *circa* 5400BC and an increase in warmer winters between 2700 to 1100BC (Göktürk *et al.* Forthcoming; 2011; In progress). And although the resolution of these records is very high with these particular records (less than a decade), the changes are discussed on a centennial basis, which unfortunately leaves out much of the finer detail. This is mainly because the authors are trying to tie in these records with regional archaeological events (such as the collapse of Tell Leilan) and other palaeoecological proxies.

Wick *et al.* (2003) found aridification trends in their multiproxy study at Lake Van (see also van Zeist and Woldring 1978, Landmann *et al.* 1996). O^{18} isotopes indicate a period of 'higher aridity' between 4100-2100 years BP (varve dates; *circa* 2100 to 100BC) (Wick *et al.* 2003; p. 670). The pollen evidence also indicates less *Quercus* pollen, signalling the 'opening of the woodlands', perhaps caused by more aridity (indicating a more long-term process: Wick *et al.* 2003; p. 670). Although pollen evidence can be questionable (see above) this does seem to correlate with the other proxies. The Mg/Ca ratio, which measures the salinity of the lake water, also shows that the water was becoming increasingly saline, although there is a lag effect here as this does not show up in the proxy until 3400 BP (*circa* 1400BC) (Wick *et al.* 2003). Roberts *et al.* (2001) found similar results at Lake Eski Acigöl, central Turkey, using diatom, isotope and lake sediment mineralogy proxies.

In the Urfa plain, Rosen (1997) found evidence of aridification in the sedimentary record: no MBA period sedimentary layers were present, possibly indicating incision of the river (see also Rosen 1998, Algaze *et al.* 1995).

2.5.2 Iraqi Kurdistan / Zagros region

To date, there has been very little palaeoenvironmental work in this region (see, for discussion: Marsh and Altaweel In press, Altaweel *et al.* 2012) and this thesis provides the first analyses on sediments and phytoliths in this region.

The Mirabad and Zeribar records were taken from the lakes of the same names in Iran, on the rain shadow (i.e., dry side) of the Zagros, and therefore could reflect vegetation that is more drought resistant than the vegetation growing on the other side of the mountains (i.e., in Iraq) (Altaweel *et al.* 2012). The evidence from Lake Mirabad (van Zeist 1966), is imprecise, but do record shifts in the climate (wet-dry phases) post 5,500BP (*circa* 3500BC).

Lake Zeribar also indicates wet-dry variations after the Mid-Holocene and an episode of aridity between circa 4.0 and 3.5BP (*circa* 2000 to 1500BC) (Snyder *et al.* 2001, van Zeist and Wright 1963, Stevens *et al.* 2001). It should be noted that the date is an estimate, taken from a point between calibrated C14 dates of 5640 (+/-70) and 2240 (+/-150) (Snyder *et al.* 2001; p. 739, Fig. 2), which underlines the difficulty in correlating proxy data with archaeological events.

2.5.3 Mesopotamia (North)

Overall, archaeobotanical evidence seems to indicate a drying trend, but one that is not as pronounced perhaps as in the Levant: there seems to be more use of crops, which were less resistant to drought even during the EBA going into the MBA (Riehl *et al.* 2009). Stable isotope analysis of plants dating from 5400 cal. BP to 2000 cal. BP (*circa* 3400-0BC) indicates that there was decreasing water availability for the plants (Riehl *et al.* 2009). In addition, detailed analysis seems to indicate that C13 increases (indicating higher moisture content in soils), and then around 4000BP (*circa* 2000BC) there is a decrease (also rapid) (Riehl *et al.* 2009). However, the samples are not robustly dated, and as Riehl *et al.* (2009) point out, some of the evidence (i.e., that from Tell Mozan in the Khabur plain) seems to indicate fluctuations in the amount of available water at this time (the EBA). There seems to be increasing water supply until 4200 cal. BP (*circa* 2200BC), with a drop between 4200-4100 cal. BP (*circa* 2200-2100BC) and then an increase again (Riehl *et al.* 2009).

The pedogenic carbonate coatings analysed by Riehl *et al.* (2009) also indicate that there was a 4.2 KY event, as the accumulation of carbonate coating on the stones seems to cease sometime around 4000 cal. BP (*circa* 2000BC). The lack of carbonate coatings is due to a lack of water in the sediments which leads to the decrease of precipitation of carbonate material. This evidence seems to indicate that the 4.2KY event was felt here, but again dating issues arise.

In the Khabur region, there is, of course, the evidence from Tell Leilan, the yellow aridification layer (Weiss *et al.* 1993, Courty and Weiss 1997), which Courty (1998) has now dated to the pre-Akkadian period. Tell Leilan and some other sites in the Khabur area did collapse or contract significantly around

2150BC, however, other sites, such as Tell Brak and Tell Mozan continued (and see articles in Weiss 2012b). Sites such as Brak, Chagar Bazar and Barri have differing histories to that of Leilan (see McMahon 2012, Colantoni 2012, Orsi 2012), although little palaeoenvironmental work has been carried out as yet.

2.5.4 Mesopotamia (South)

There is evidence of general aridification, which some have said caused the fall of the House of Akkad (Weiss *et al.* 1993). A 'sudden', short-term aridification event was postulated by Weiss and others (Weiss *et al.* 1993, Cullen *et al.* 2000), based on aeolian sediments in a Gulf of Oman core and a yellow layer at Tell Leilan (subsequently redated to an earlier period by Courty (1998). This evidence has been questioned by other scholars, including Wilkinson (1998) and Rosen (2007) who consider the 4.2KY event a longer-term aridification trend as opposed to a drought (see discussion above and Weiss 2012c).

Kuniholm (1990; p. 647) also points out that farming in this region must have 'always [been] precarious', relying on irrigation. In the alluvial plain of the Tigris-Euphrates valley, rainfall was variable, and societies were more reliant on canal irrigation (Roberts 1998). Gradual drying conditions and salinisation (resulting from the combination of human modification and natural processes: canal irrigation and high evapotranspiration rates) may have led to a decrease in cereal and other crop fields (Altaweel and Watanabe 2012, Jacobsen 1982, Jacobsen and Adams 1958). This, in turn, may have led to different agricultural strategies being adopted, for instance leaving fields fallow, switching to barley and finally abandoning fields (Roberts 1998, Altaweel and Watanabe 2012).

However, the extent of salinisation in this region and its effects on socio-economic change has yet to be proven, and much is still assumed (Altaweel and Watanabe 2012). While textual evidence may refer to declines in crop yields and salinisation mitigation, they do not provide evidence for the existence (or nonexistence) of an 'abrupt megadrought' as postulated by Weiss (2012c), even in this region.

Nor is the full extent of the role of human agency appreciated or discussed in many of the case studies, not only in southern Mesopotamia, but across the region. Chapter 4 will present a discussion of niche construction theory and human modification to environments, which can lead to environmental and cultural change.

Chapter 3

The sites

Two sites, Hirbemerdon Tepe in southeast Anatolia and Bakr Awa in Iraqi Kurdistan, have been chosen for this thesis. These two sites were chosen primarily because of their similar montane environmental settings and because they covered similar time periods. In this chapter is a general discussion of the natural and cultural environments: geology, land use, climate and archaeology. Where possible, specific 'historical' dates are used, adopting the Middle Chronology, with the full understanding of its problems; other 'date' references are typological (Old Babylonian, Akkadian), and are used to describe various archaeological units at Bakr Awa. The dating at Hirbemerdon Tepe tended to be on a broader timescale: Early Bronze Age, Middle Bronze Age. Some C14 dates were obtained for both sites, which have been calibrated.

3.1 Hirbemerdon Tepe and its environs

3.1.1 Environment and geomorphology

Location

Hirbemerdon Tepe is a tell site located in the foothills of the Ramandag/Tur 'Abdin mountains, near the confluence of the Batman Sur and the Tigris river in the Diyarbakir province, southeast Anatolia (see Figure 3.1). It is situated on the west bank of the Tigris and is about 40km south of Bismil. It is separated from the Jezireh plain, which runs from the Euphrates to the Tigris, by the Tur

’Abdin mountains. Essentially it is an alluvial, montane landscape, and is situated at political, geological and river boundaries. The Batman river divides the modern provinces of Batman and Diyarbakir. In the past, the river separated the Roman from the Parthian / Sassanian empires (Ur 2007).

This region has been little studied until recently. However, with the advent of the Ilisu dam construction (part of the Southeast Anatolia Project (GAP): see IEG 2001; Figure 3.2), there has been a large archaeology rescue programme with new and previously known sites being surveyed, excavated and recorded along the Tigris river valleys (see Tuna *et al.* 2001, Ur 2007).

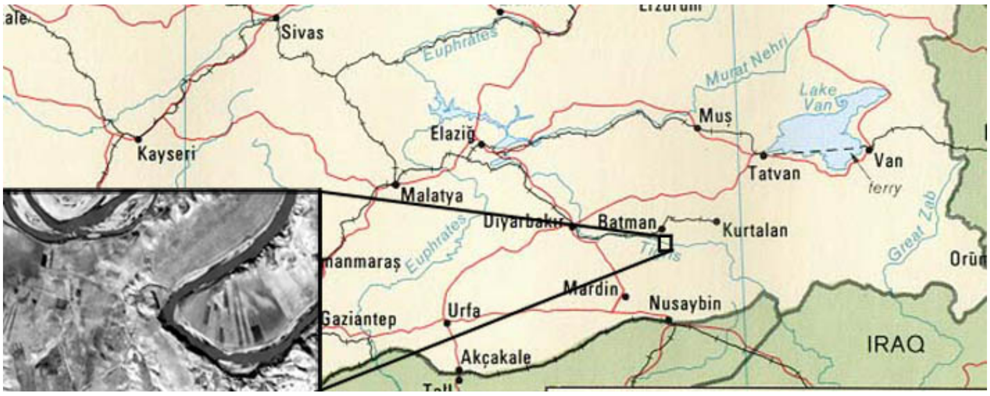

Figure 3.1: Map of region, with detail of the location of Hirbemerdon Tepe. Map from (Crowe 2014), aerial photo courtesy of Nicola Laneri

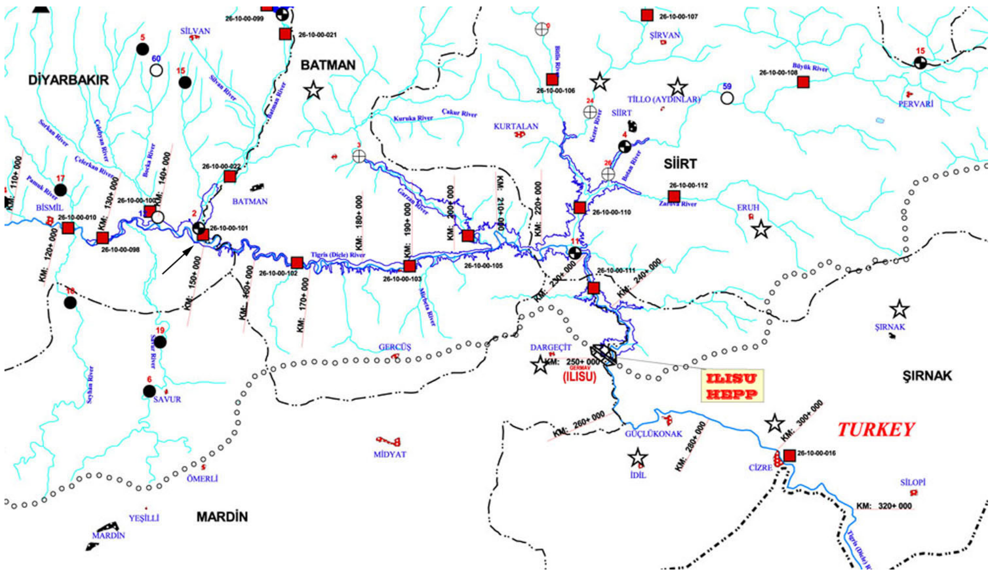

Figure 3.2: Map of Ilisu dam project. Hirbemerdon Tepe is located north of Ilisu, and south of Batman, indicated by the arrow. Map modified from IEG (2001), Appendix 1

Climate

The climate is, generally speaking, Mediterranean, that is, with cold, wet winters and hot, dry summers, with most precipitation in the winter months. It is also described as semi-arid in the IEG (2001) report.

The climate regime across Turkey varies because of the contrasting topography (coastal versus montane versus continental) (Dewdney 1971). There are seven different classifications according to Türkeş *et al.* (2008): Black Sea (BLS), Marmara Transition (MRT), Mediterranean (MED), Mediterranean Transition (MEDT), Continental Mediterranean (CMED), Continental Central Anatolia (C CAN) and Continental Eastern Anatolia (CEAN) (see Figure 3.3). The study area falls under Continental Mediterranean.

At Urfa, for records from the 1960s-70s, the average rainfall was 452mm / yr, with a temperature range of 5°C in January and 32°C in July (Dewdney 1971; p. 89, Table 1). This contrasts with the mountainous interior where conditions are cooler (0-5°C in January, 15-25°C in July: Dewdney 1971). This region is also much warmer than elsewhere in Turkey in the summer (Dewdney 1971), and the IEG (2001) note that summer temperatures exceed 40°C during the summer. In the summer 2008 season, we experienced temperatures exceeding 40°C. There is very little precipitation in the summer months in the general region (at Urfa, there is practically none: Dewdney 1971), however, this will vary locally; most precipitation occurs in the winter and spring months (IEG 2001).

The level of precipitation may also be decreasing slowly in this region (Türkeş *et al.* 2008). At Kiliş, which has a similar climate regime and is located due southwest of Hirbemerdon Tepe, precipitation was about 300mm, with an average of 275mm / year winter precipitation between 1930 to 2000 (Türkeş *et al.* 2008). The IEG (2001) state that at Bismil (located just due north of the study area) the average rainfall was 400mm.

Land use and vegetation

A major part of the Turkish economy is based on agriculture, which is evidenced by the Güneydoğu Anadolu Projesi (the Southeastern Anatolia Project or GAP), which includes irrigation schemes. Mechanical irrigation is necessary

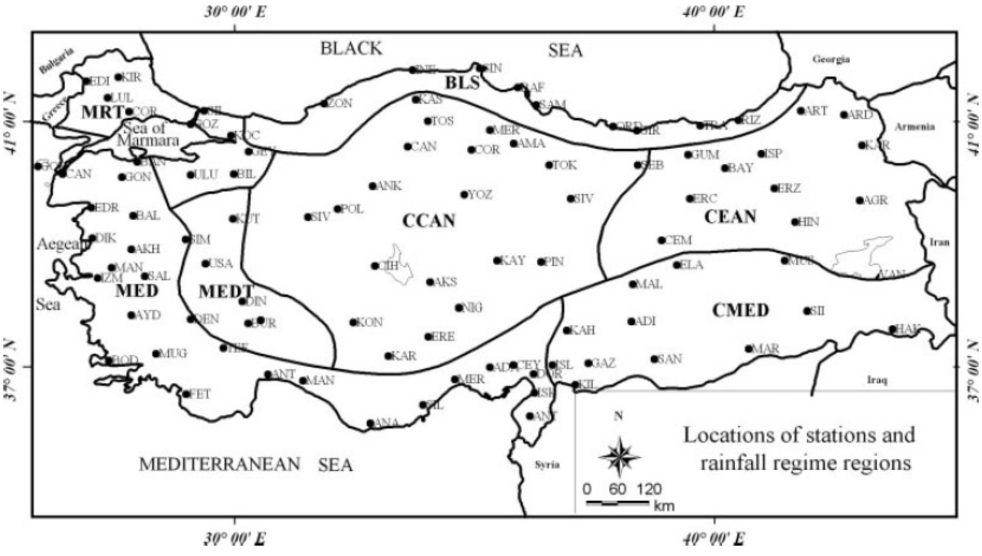

Figure 1. The locations of stations and rainfall regime regions over Turkey. BLS, Black Sea; MRT, Marmara Transition; MED, Mediterranean; MEDT, Mediterranean Transition; CMED, Continental Mediterranean; CCAN, Continental Central Anatolia; and CEAN, Continental Eastern Anatolia.

Figure 3.3: Climate zones of Turkey. The arrow indicates the approximate location of Hirbemerdon Tepe. Map modified from Türkeş *et al.* (2008), p. 3, Fig. 1

in this region largely because of the more intensive modern agriculture, lack of summer rains and unpredictable rainfall patterns. Although precipitation can average above the 250mm a year necessary for rain fed farming, often it is much below this (see for more information: Türkeş *et al.* 2008). Crops grown in Turkey include cereals (wheat, barley, rye), legumes, cotton, tobacco, and others (Dewdney 1971, IEG 2001). The cultivation is intensive, with both winter and summer crops grown. Although the IEG (2001) indicates that the study area agricultural fields are non-irrigated, the fields are certainly now mechanically irrigated as evidenced by large pipes and collapse of the river terrace edges (see Figure 3.4). Very few areas in the highlands are cultivated – only areas where the soils are deeper (and therefore better developed) and on gentle slopes (Ur 2007).

Much of the area is also used for grazing, mainly sheep and goat, and to a lesser extent, cattle (IEG 2001). In the local region, due to topographical constraints, agriculture is limited to the lower terraces, such as at the Batman-Tigris confluence, with pastoralism being the norm in the uplands (see IEG 2001). Grazing also takes place on the agricultural fields post-harvest, or when fields are left in fallow. The uplands in the local area are essentially denuded of vege-

Figure 3.4: Irrigation erosion at the edge of the terrace. Photo taken from the tell, about 200 metres away

tation, particularly of trees. Any extant vegetation is steppic, with some grasses and shrubs. Zohary (1973; pp. 33 and 181) describes the vegetation of this region as steppic forest and ”Irano-Turanian ground and interspace vegetation’ with oak woodland and steppic flora; since then it has not changed much: the IEG (2001) describe the vegetation as steppic as well, with some shrubs, oak and juniper. No trees were seen in the uplands in this vicinity, and the IEG (2001) report states that much of the uplands vegetation has been affected by deforestation and grazing.

Geology

The site lies on the Diyarbakir-Siirt plateau, which is part of the larger Syrian-Arabian platform (Altini 1966), or Arabian plate. The area is mountainous and tectonically active due to its position near the convergence of four plates, the Arabian, Iranian, Turkish and European, and fault zones, including the Dead Sea Fault to the southwest, East Anatolian Fault to the northwest and the Zagros thrust to the east (McClusky *et al.* 2000; see Figure 3.5). The plates are colliding with each other, resulting in folding and upthrust of mountains.

The surrounding region is undulating, with chains of mountains, which run

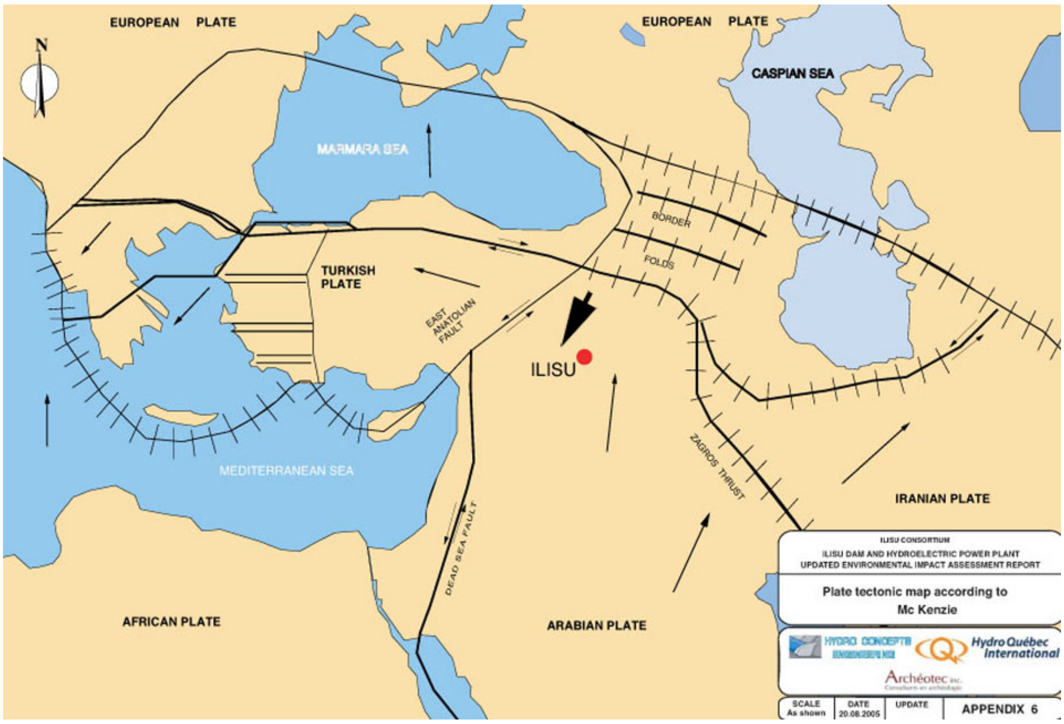

Figure 3.5: Map showing the different colliding plates and fault zones in the region, the arrow indicates the approximate location of Hirbemerdon Tepe. Map modified from: IEG (2001), Appendix 6

Figure 3.6: View of Syria and the Jezireh plain from Mardin

on an E-W axis and the elevations vary from circa 1800m to circa 500m (Tolun 1962, IEG 2001). The mountain ranges and Turkey as a whole are most likely a continuation of the Himalayan-Alpine belt (Kamen-Kaye 1971, Evans 1971). The area of Hirbemerdon Tepe is bounded by the Tur 'Abdin mountains to the southeast, the Diyabakir plain to the northwest (elevation of 575m: Tolun 1962) and the southeastern Taurus (the southeastern Anatolian overthrust: Demirkol 1989) in the north. To the southwest is the Harran plain and slightly east of this, and divided from the plateau by the Tur 'Abdin mountains (the Mardin block: Tolun 1962), is the Jezireh plain (see Figure 3.6).

The geology of the environs of the site consists of mostly outcropping Miocene deposits, with Middle Eocene Midyat (limestone) formations at higher elevations due southeast of the site area (Tolun 1962, IEG 2001). The lower facies of this limestone also contains chert nodules, which would have been used in tool manufacture in the area (I noted flint tools and cores in the gully sections). The Midyat formation can be found adjacent to the site, just southeast, where the Tigris cuts into the limestone. It is easily recognisable due to its colour and friable nature.

The lower plateau area, such as where the site is located, situated at *circa* 550m asl, is covered in Miocene deposits (see Figure 3.7). Doğan (2005b) differentiates between upper and lower Miocene deposits: the Selmo (upper) and Germick (lower). The two deposits are superficially similar, containing clays, sandstones, conglomerates and limestone and other sediments. However, the lower deposit is also characterised by the presence of salts: anhydrites and gypsum (Doğan 2005b). On the other hand, the IEG (2001), in its geology map of the region (Appendix 8), shows that the Germik formation is associated with the Eocene Midyat formation, although in the text (p. 3-16), the Germik is not even mentioned. It is likely that the map was mislabelled. The Selmo formation, however, is described as having gypsums. The presence of this gypsum is important to the formation of the tell site, as will be discussed further below.

Quaternary alluviation has covered much of the Miocene deposits and created the various river terraces, which are also discussed in more detail below.

Figure 3.7: Geological section found adjacent to Hirbemerdon Tepe and the Tigris river. The white Middle Eocene Midyat formation is covered by the later reddish Miocene littoral to terrestrial deposits. Note small cave entrance at bottom

Geomorphology

Because of the varied topography of the area, there are many different processes acting on the landscape as well as the site itself. These include fluvial and aeolian transport and deposition of sediments, fluvial incision, tectonic uplift and chemical and physical weathering (to different degrees) of the exposed bedrock and sediments. The tell itself is subjected to depositional and erosional processes (by wind, stream action, gravity and humans). Colluvium is also present in the area.

Streams (present and past) tend to run in a N-S direction, perpendicular to the mountains (Tolun 1962) and then run into higher order collector rivers such as the Batman and the Tigris. The relative softness of the Eocene limestone makes it conducive to weathering and incision by stream action (creating deep valleys: Tolun 1962) and the Miocene deposits are highly erodible, contributing to the sediment load of the rivers and making up the terrace sediments. There are also palaeochannels – old wadis – in the area.

Quaternary river terraces are evident in the plain area and are particularly apparent on the Batman and Garzan rivers (Tolun 1962, IEG 2001) as well as this part of the Tigris (see Figure 3.8). Doğan (2005a) has done much research

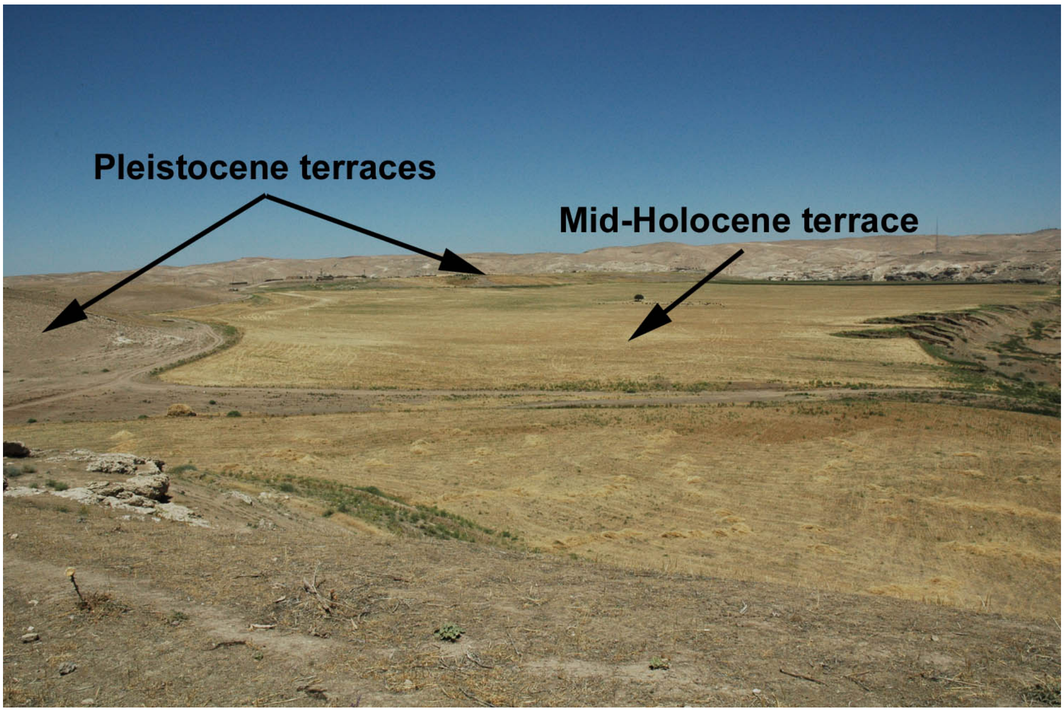

Figure 3.8: View from Hirbemerdon Tepe of the Mid-Holocene terrace and distant Pleistocene terraces which appear as low hills. The furthest Pleistocene terrace is about 1 kilometre away

dating these river terraces. The terraces were created through deposition of alluvial sediments, as well as vertical movement in the region (Tolun 1962). Upthrust, caused by tectonic activity, is continuing into the Quaternary (Tolun 1962), explaining some of the heights of the older terraces (there are several faults just due northeast of the site).

According to Doğan (2005a), there are five terraces in the area between Bismil and Batman: T1, the oldest (+40m), T2 (+30m), T3 (+10m), T4 (4-5m) and the youngest, T5 (2-3m). T1 to T3 are Pleistocene in age, T4 and T5 are Holocene (Doğan 2005a). The IEG (2001) report also lists five terraces along the Tigris, however with some variation: there is an additional Pleistocene terrace at 20-25m, and the second Holocene terrace, T5, is not listed; the heights of the terraces are also somewhat greater (by a few metres). Terraces of different ages are very difficult to distinguish, and will vary along the river channel, so there is often discrepancy in descriptions.

Hirbemerdon Tepe is on the edge of the Batman-Tigris confluence and just outside Doğan's study area. The general area is characterised by a wide alluvial setting consisting of river terraces, floodplains of varying sizes and the occasional Miocene outcrop. This landscape changes quite abruptly into the uplands as the Tigris river wends its way east. It is at this point that Hirbemerdon Tepe is located. I located four terraces in the immediate environs of Hirbemerdon Tepe (T1 to T4). There may have been traces of the fifth and youngest terrace, upstream from the site (and as mentioned above, the IEG report doesn't recognise this terrace). Since terraces 1 to 3 are Pleistocene in age, they will not be discussed in detail in this thesis. The Holocene terrace T4, was located and it abuts T3, a Pleistocene terrace. T4, is discussed in more detail in Chapters 6, 7 and 8.

Comparisons between the Hirbemerdon Tepe (T4) terrace and the other Mid-Holocene terraces in the southeastern Anatolian and northern Syrian regions will be made in the Chapter 7, to find parallels and differences which can highlight variations in climate and environmental change across the region and how it differentially impacted the hydrological and sedimentary records.

At this point, no detailed analyses have been made regarding formation processes affecting Hirbemerdon Tepe itself, however, some general comments can be made, based on the survey of the geology. The site itself is not a typical tell, in that it is not situated on a Pleistocene terrace or alluvial plain. It is on an outcrop, in this case, consisting of Miocene deposits, and this outcrop appears to be bowl-shaped, as if the middle of the outcrop collapsed to form a lake or bowl-like feature. The early phases of the site (Early Bronze Age through the Middle Bronze Age) were actually adapted to this feature, as terracing (later to be infilled and levelled out: Laneri *et al.* 2008). Because of this unusual feature, the tell formation processes were different in the earlier EBA to MBA phases than in later phases.

Doğan (2005b) has studied the karstification, caprock dolines and other subsidence processes of the region between Bismil and Batman, just a few kilometres due north of Hirbemerdon Tepe. What he found is that the gypsum-rich Germik/Selmo formation dissolved in some areas, creating fairly large sinkholes and caprock dolines. The IEG (2001) also notes sinkholes and dolines forming as a result of the gypsum content. The study area (Hirbemerdon Tepe) contains both features: the Miocene caprock dolines seen in Doğan's study area (due north) and limestone karstification of the uplands. The Germik/Selmo

Figure 3.9: Karstic-like basins in the surrounding low hills, located about 150 metres from Hirbemerdon Tepe

formation in the Hirbemerdon Tepe area is less substantial, and the gypsum content is not visible as seams, but rather as clumps here and there. However, there are dolines in the area (see Figure 3.9), including one in the tell itself. It would seem that the gypsum content is more substantial than what appears in section. The doline formation occurred pre-occupation (as evidenced by the MBA terracing into the sides of the basin).

As discussed above, both the Germik and Selmo formations are present here. This combination, with the variant colours (red, and the greens and greys) that characterise these deposits, along with early Quaternary alluvium within the basin, accounts for the variety of 'virgin soils' encountered on the mound site (there were at least four: red, red rocky, grey and grey rocky). Green clay was also found.

The site formation processes within the basin during occupation included *in situ* weathering of the bedrock and architectural features, building collapse (buildings fall out of use, even during occupation), build-up of human waste products (rubbish, manufacturing debris, and so forth) and colluvium falling into the basin. After abandonment, there were the additional processes of further roof and wall collapse, mudbrick disintegration, stream action weathering and erosion (the rainwater would have been better contained during occupation as evidenced by the presence of drainage: Laneri *et al.* 2006). Essentially the site collapsed on itself.

Later, the basin was purposefully filled in and levelled out, and further occupation began on top of this, initiating 'normal' tell formation (and erosion). This included successive building on previous occupations, settlement movement around the tell, building collapse, mudbrick disintegration, wind and stream action, to name a few (for more detail on tell formation, see Rosen 1986).

Hirbemerdon Tepe is bordered on the east by the Tigris, which is currently incising (although stream power will fluctuate a lot due to the damming further upstream). Incision will erode and has eroded the terrace (T4) in which the Outer and Lower Towns are located, as well as other settlements. There is also a wadi, or irrigation channel, the age of which is undetermined (Figure 3.10). Parts of the channel look natural, although areas have been reinforced with cement and other areas may have been deepened (N. Laneri, pers. comm.). This wadi is eroding the north side of the Outer Town. In the past, there was heavy alluviation (as evidenced by the height of T4) as well as possible high energy flash flooding episodes.

Alluviation would have had both an erosive and preservative effect on the archaeology in the terrace, depending on the individual site's location. The flash flooding episode(s) as evidenced in the terrace sections (see Chapters 6 and 7) would have been more high energy and therefore more destructive.

The irrigation damage illustrates another, current danger to the archaeology in the area. Jason Ur and his team have discovered a number of sites within the terrace (Ur 2007), however much of this will be damaged by the intensive farming (ploughing, churning up artefacts and destroying architectural features, for example) as well as the irrigation, which is drastically eroding the sides of the terraces. In the future, as a result of the GAP damming, this area will be submerged. As of the summer 2011, the site has been closed down and covered in sand.

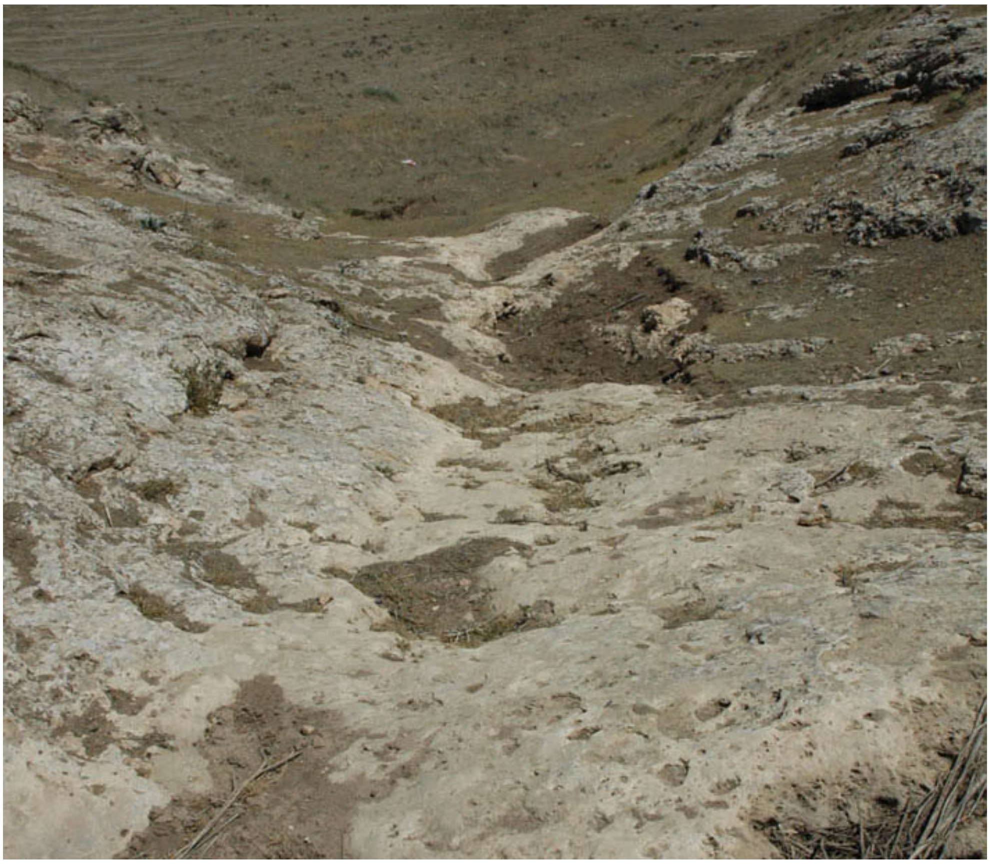

Figure 3.10: Part of the wadi eroding through the bedrock near Hirbemerdon Tepe. The wadi is not very wide, perhaps just over a metre wide in this section

3.1.2 Regional context

The Hurrian link

The site is located in an area which was known as Subartu, land of the Hurrians in ancient texts (Laneri *et al.* 2006). Subartu covered an area in southeast Anatolia, parts of northern Syria and northwest Iran (Laneri *et al.* 2006). The Hurrians originated from the mountains of the east Taurus or Zagros (or northwest Iran: Soden 1994), and their language seems to have a link to some Semitic languages (Wilhelm 2008). Tell Brak and Tell Mozan are both located in the Khabur basin, just south of Hirbemerdon Tepe and on the other side of the Tur 'Abdin mountains. There is evidence that after the fall of the House of Akkad, the Hurrians took control of some Akkadian settlements including Brak and Mozan.

However, in the Khabur region, there is other evidence that the Hurrians were present there from at least the Akkadian period (Wilhelm 2008, Veenhof 2008), so there doesn't seem to have been an invasion. Brak was probably the ancient town known as Nagar in documents from Ebla, Mari and elsewhere (Eidem *et al.* 2001, Oates and Oates 2001a). In later inscriptions Brak was known as Nawar and Mozan as Urkesh (Akkermans and Schwartz 2003), and a door sealing found at Brak has an inscription for the Hurrian king Talpusaili (Oates and Oates 2001a). At Tell Mozan, there is also a third millennium temple platform that the excavators attribute to the Hurrians (Buccellati and Kelly-Buccellati 1997).

There is further evidence of a link between southeast Anatolia and the Khabur triangle with Brak acting as some sort of 'gateway' between southeast Anatolia and northern Mesopotamia (Oates and Oates 2001b; p. xxv) and Mozan on the route to the Ergani mines in Anatolia (Akkermans and Schwartz 2003, Buccellati and Kelly-Buccellati 1988). Hirbemerdon Tepe, located on the Tigris, is also on the way to the Ergani mines (see Figure 3.11). It seems unlikely that there was no contact or trade between the Hurrians, the Khabur area and Hirbemerdon Tepe.

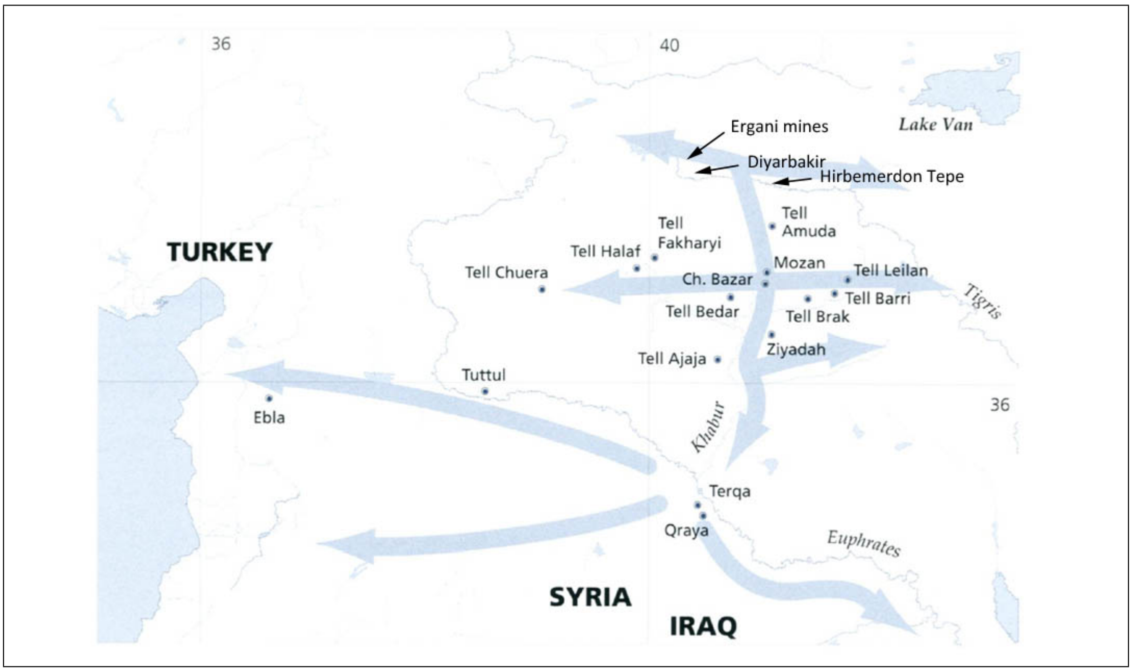

Figure 3.11: Map showing possible trade routes from the Khabur region. Note that the Ergani mines are upstream from Hirbemerdon Tepe. Some of the major sites discussed in the text are also highlighted here. Modified map from Buccellati and Kelly-Buccellati (1997; p. 78)

The Hittites were also a powerful entity in Anatolia and by 1800BC controlled much of central Anatolia (Soden 1994), with their capital established at Hatussa. Although Hirbemerdon Tepe is outside Hittite territory, there may be a link, in terms of the deer cult, which will be discussed in more detail in Chapters 7 and 8.

The Khabur region

At the time of the Akkadian 'collapse', Tell Brak and Tell Mozan, unlike Tell Leilan, also in the Khabur triangle, show little or no sign of contraction let alone collapse (Oates and Oates 2001a;b, Akkermans and Schwartz 2003, Dolce 2008, Weiss 2012b; articles therein and Chapter 2). Indeed, there is evidence of continued monumental construction at Mozan and Mari, southeast of Tell Brak (Akkermans and Schwartz 2003, Buccellati and Kelly-Buccellati 1997).

There are mixed stories in terms of collapse and continuity in Anatolia. Although the traditional picture is one of widespread collapse at the end of the third millennium BC, there seems to be more continuity than presumed. For instance, along the middle Euphrates, although some sites, such as Jereblus Tahtani, collapse, others continue to flourish, such as Horum Höyük, Carcamesh and Tell Amarna (Marro 2007).

In northern Syria (Upper Mesopotamia), the evidence is also mixed in terms of continuity, contraction and collapse. According to Felli and Merluzzi (2008; p. 97), the evidence for widespread collapse in this region is not as 'pervasive' as originally thought. Some sites do collapse, such as Umm el-Marra, however, many continue through the EB-MB transition, including Tell Kabir, Tell Sweyhat, Ebla, Mari (the last two being major urban sites) and Tell Afis (Felli and Merluzzi 2008, Dolce 2008). Tell Afis, the site that these authors excavated, in fact, seems to 'prosper' at the end of the third millennium (Felli and Merluzzi 2008; p.102). Cooper (2006a;b) has found similar evidence of mixed fortunes in the region. A similar trend seems to be occurring in southeast Anatolia, with new settlements being founded (Laneri *et al.* 2006), such as Salat Tepe, Hirbemerdon Tepe and Kenan Tepe.

So, although there is some collapse and contraction in the region, other sites continue and some new sites are even founded, in a period of apparent deteriorating climatic conditions. The seeming collapse cycles in more southern parts of Mesopotamia may be more due to political reasons than environmental ones. For instance, Pollack (2004) proposes that in the Akkadian period, the capital was moved from the Uruk region (south) to the north in Agade; then with the establishment of the House of Ur, the capital was moved back down south to Ur. When the capital was moved to Agade, settlements in Uruk declined and settlement in the Nippur-Adab region increased; when the capital was moved to Ur, the reverse happened (Pollack 2004).

3.1.3 Survey and archaeology of Hirbemerdon Tepe

Survey of Hirbemerdon environs

In the last 20 years or so, since the initiation of the Ilisu dam phase of the GAP, the upper Tigris Valley region has been surveyed fairly extensively. The immediate 5km area around Hirbemerdon Tepe will be discussed here (see Figure 3.12). This survey information gives more data on the pattern of habitation in the region, across the agro-pastoral spectrum. The purpose of the 2007 survey was not only to locate and record other (sedentary) settlements within the immediate environs, but also to look for evidence of nomadic/pastoral activities in the uplands (Ur 2007).

The area surveyed was about 4.8km^2 (5km radius) on the southern side of the Tigris and used intensive techniques, such as transect walking, where feasible. Some areas, unfortunately were not so easily surveyed due to visibility problems (Ur 2007). Several sites where found in the vicinity, including one Neolithic in date, and two Medieval / Islamic sites (Ur 2007, Laneri *et al.* In press). The team also found a pottery scatter near the tell site itself; the pottery dates to the MBA so this is considered a sort of 'suburb' of the main site (Ur 2007; p. 3). Other sedentary settlements were discovered in the cultivated uplands areas, for instance a Hellenistic period site near Tepekonak, 3km due southwest of Hirbemerdon Tepe (Ur 2007).

Figure 3.12: Area surveyed around Hirbemerdon Tepe, showing pottery densities and possible sites (numbered). Map modified from Laneri *et al.* (In press), Figure 20

There is no doubt that other sites exist in this vicinity, and many others along the Tigris which will escape and have escaped detection. Some will have been destroyed through ploughing, river erosion and so on, others will be buried, especially in the floodplain areas, by alluvium.

In the uplands, the Hirbemerdon Tepe survey team was able to document several campsites and cemeteries – possible nomadic activity (Ur 2007). Although the sites were more modern, they do indicate the type of structures and evidence that might be left behind. For instance, one site, only recently abandoned, had a series of rectangular low walls. These walls had never stood very high and were used to pitch tents on (bayt-shaar type: Ur 2007). There is also evidence of water management: cisterns and diversion channels were constructed near wadis (Ur 2007).

In addition, 'kurgans', piles of round rocks, were also found across the uplands. These may signify burial spots of nomads and some were found in clusters, others in isolation (Ur 2007).

Archaeology on the tell

The site itself is circa 10.5 hectares and consists of an upper town (the 'High Mound'), lower town, outer town and a possible outer 'suburbs' area (Ur 2007). The upper town consists of a high mound of circa 4ha, with an elevation of 610m asl (see Figure 3.13). The lower town is about 3ha, the outer town is circa 3.5ha (Laneri *et al.* 2006).

The excavation of Hirbemerdon Tepe formed part of the larger Ilisu dam rescue project and was an international collaboration between the Archaeological Museum of Diyarbakir and the Instituto Italiano per l'Africa e l'Orient (IsIAO) (Laneri *et al.* 2007). The project was started in 2003 and finished in the summer of 2011, at the instigation of Diyarbakir Museum.

The aim of the project was firstly working as part of the overall Ilisu dam rescue project (see for reports from other sites: Tuna *et al.* 2001). Secondly, it was hoped that through intensive excavation, survey, and the use of new technologies such as geophysics and GIS, a better understanding of the region and the relationship between southeast Anatolia and Northern Mesopotamia could be achieved (Schwartz 2007). The geoarchaeological component of this project will help to reconstruct the environment and also shed light on the socio-politico-economic changes that occurred in the context of the changing environment.

Several phases of occupation were indicated by excavation (see Table 3.1). There was initial occupation in the Chalcolithic period (4th millennium BC), followed by a hiatus (Laneri *et al.* 2006; 2007). The site was then reoccupied in the Early Bronze Age (EB I) to Middle Bronze Age (circa 3000 to 1782 BC: Laneri *et al.* In press). It is during MBA that this site was most prominent. There is evidence of habitation into the Late Bronze Age (later Khabur and Nuzi

Figure 3.13: View of Hirbemerdon Tepe from the banks of the Tigris, about 200 metres away

ware fragments) (Schwartz 2007), which may be indicative of a slow decline then abandonment of the site. This period was followed by another hiatus, and reoccupation did not occur again until the Iron Age (late second to the first half of the first millennium BC: Laneri *et al.* 2006, Schwartz 2007). The final phase of occupation occurred during the Islamic period (12th to 14th centuries AD) (Schwartz 2007, Laneri *et al.* 2008).

The majority of the pottery from the main MBA period found all over the site is locally produced red brown wash ware (RBWW) (Figure 3.14), which is rarely found outside of the Upper Tigris region (Laneri *et al.* 2007, Schwartz 2007). Much of this consists of coarseware storage jars (Laneri *et al.* 2006). There is other pottery from Sub-phase B (early to mid-MBA), dark-rimmed orange bowls (DROB ware) (Figure 3.14), which is also found in the post-Akkadian levels at Tell Brak and Tell Mozan in the Khabur region, as well as at Ziyaret Tepe and Kavusan Tepe in the upper Tigris valley (Laneri *et al.* 2006; 2007, Matney *et al.* 2002, Schwartz 2007, Laneri *et al.* In press).

There are other ceramic parallels with the Khabur region (pseudo-Khabur assemblage – painted ware) and contact with central Anatolia (shaft-hole axe and pottery: Schwartz 2007). This suggests a link, although not a surprising one. As discussed above, there is evidence that the Hurrians came down from this area into the Khabur region. In addition, one of the portable hearths discovered on the High Mound resembles hearths found in post-Akkadian (early second millennium) contexts at Tell Mozan (Laneri *et al.* 2007).

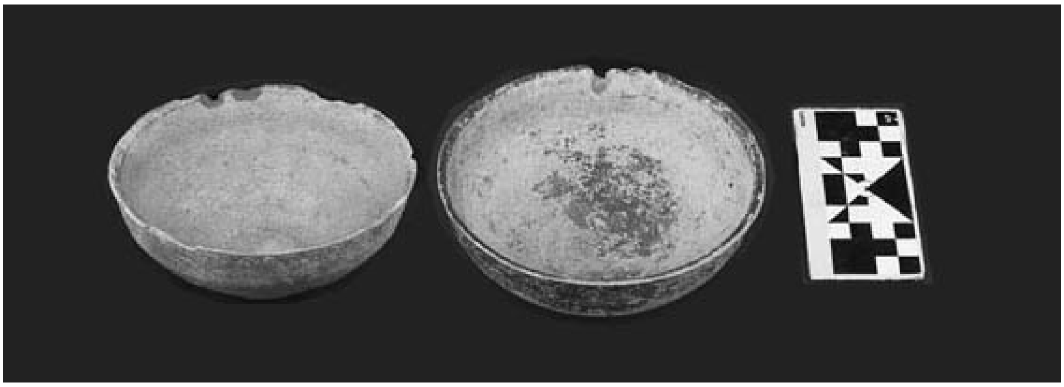

Figure 3.14: RBWW bowl (left) and DROB ware bowl (right) found in Area B. Image modified from Laneri *et al.* (2006), p. 183, Fig. 10

Chalcolithic traces were found in the Outer Town area, underlying a yellowish sandy, possible flood layer (Schwartz 2007; and see discussion in Chapter 7). The finds consist mostly of large fragments of handmade pottery (Chaff-Faced ware), which are found along the Upper Tigris region (Schwartz 2007, Laneri *et al.* 2006). In the Outer Town area, the later Early Bronze Age is indicated by architectural features, including a foundation platform, composed of river pebbles and similar sized stones and manufacturing areas (Laneri *et al.* 2006).

The upper or High Mound (dating to *circa* 2300-1600 BC) has evidence of some possible 'monumental' building with drainage channels, mostly made of mudbrick although limestone and river stones were also used (Laneri *et al.* 2006; 2007; In press). Thick platforms and foundations were installed from the earliest period of this phase (Laneri *et al.* 2007), again indicating substantial investment from early on (or perhaps reinvestment). The mound was extensively occupied, and also had terraces cut into the sides to level the slope (Laneri *et al.* 2007; 2008). The monumental structure is impressive (Schwartz 2007), indicating that this settlement was prominent, albeit in a rural context. There is a series of buildings, with associated finds of basalt grinding stones, limestone mortars, storage jars, etc, indicating a possible link to food processing and storage activities (Laneri *et al.* 2007, Schwartz 2007); these rooms were modified in subphase B, during the MBA (*circa* Ur III period; subphase A is dated to the late EB-MBA, *circa* Akkadian / post-Akkadian).

There is also an external courtyard, which seems to be a central place and has a different function: votives were found here that weren't found in other parts of the site (Schwartz 2007). In the 2008 season, an MBA 'upper platform' area (including Building Q – see Chapter 7) was exposed including several hearths (tannour type). Further crop processing areas were also examined and recorded. In subsequent seasons (2009, 2010, 2011), the excavations in the architectural complex (the 'monumental' building) were expanded to reveal another part of the building and a courtyard area (Laneri *et al.* In press); staircases, streets and drains were also excavated. In addition, animal bones were found on site, including those of deer (see Chapters 7 and 8). The outer town area, during this period, seems to have been predominantly where craft manufacture was carried out (Laneri *et al.* In press).

PHASE	DATES	PERIOD	ARCHAEOLOGICAL TRACES
I	4000-3500 BCE	LC3	*Architecture:* Disturbed walls and a large pit with burnt traces and abundance of pottery in the Outer Town (Area B); *Pottery*: Chaff-faced ware; *Other*: Obsidian objects
IIA	3000-2750 BCE	EBA I	*Architecture:* Rounded buildings and a ritual feature in the southern section of the High Mound (Area D); *Pottery:* Fingernail incised ware, Fine ware, Simple ware; *Other:*Unbaked animal figures, decorated andirons
IIB	2750-2500 BCE	EBA II	*Architecture:* Domestic architecture in the eastern section of the High Mound (Area E); *Pottery:* Fine ware, Ninevah V ware, Stone ware, Red Black Burnished ware, Simple ware; *Other:* Animal figurines, metal objects, textile tools
IIIA	2500-2000 BCE	EBA III-IV	*Architecture:* Disturbed architecture in the northern side of the High Mound and large platforms in the Outer Town; *Pottery:* Dark Rimmed Orange bowls (DROB), Stone ware, Red Brown Wash ware
IIIB	1975-1782 BCE	MBA	*Architecture:* Architectural complex in the northern side of the High Mound and architecture in the Outer Town; *Pottery:* RBWW, Band Painted ware; *Other:* Ritual paraphenalia, portable hearths, groundstones
IIIC	1450-1350 BCE	LBA	*Architecture:* Architectural features in the northern side of the High Mound; *Pottery:* Nuzi ware, late Khabur ware, Common ware

Table 3.1: Chronology of Hirbemerdon Tepe. The main periods discussed in this thesis are listed. The gap between Phase IIIA and IIIB is due to C14 dating, the gap between Phase IIIB and IIIC is likely abandonment. Table redrawn from Laneri *et al.* (In press)

Late Bronze Age traces have been found on the High Mound, including Nuzi and later Khabur ware pottery. A few whole skeletons of equids have also been found, purposefully buried here (Schwartz 2007), the significance of which is still being investigated. The Iron Age features on the High Mound include a few poorly preserved stone walls and pottery (e.g., Grooved ware, Plain Simple ware) (Schwartz 2007). Iron Age pottery (Grooved ware for example) and basalt objects (bowl and grinding maul) were found at the Outer Town – the basalt artefacts links this site to other Syro-Anatolian Iron Age sites in the upper Tigris region (Schwartz 2007, Laneri *et al.* 2006).

The Islamic period is ill-defined on the High Mound, with some badly decayed architectural features and glazed Islamic ware (Schwartz 2007).

3.2 Bakr Awa and its environs

3.2.1 The environment and geomorphology

Location

Bakr Awa is the largest tell located in the Shahrizor plain circa 7km north of Halabja and just south of the Darband-i Khan dam lake (see Figure 3.15). Bakr Awa was first described by James Felix Jones in 1844, and has been subject to much looting, particularly in the Lower Town area (Miglus *et al.* 2011). This is evidenced by the many robber pits in the area. The Shahrizor is a largish plain and forms part of the Shahrizor-Piramagroon basin (Ali 2007). It is surrounded by the Binzird, Baranan and Qara Daghs to the west and the Zagros mountains to the east.

The Tanjero, a major river that runs from the northwest into the Darband-i Khan lake (north side), and the Sirwan (upper Diyala) flows from the lake, down towards the Mesopotamian plain and the Tigris. The Darband-i Khan dam lake marks the area where three major rivers had their confluence: the Sirwan, Tanjero and Zalim. There are also many streams, mostly seasonal wadis, which criss-cross the plain. The plain is more or less flat, but is marked by the higher elevations of Pleistocene terraces, hills and fans at the base of the slopes

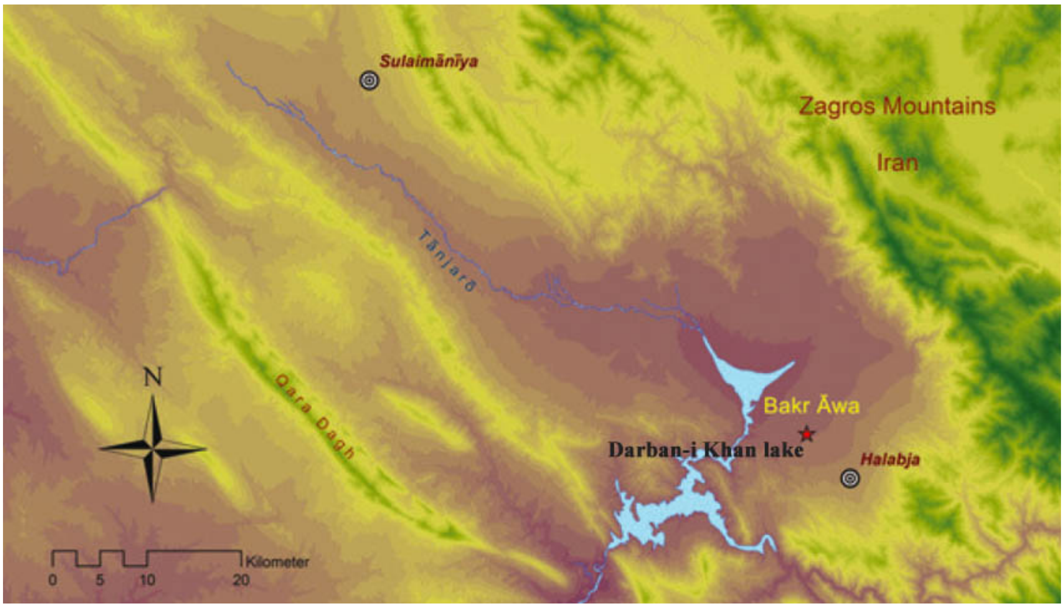

Figure 3.15: Location of Bakr Awa in the Shahrizor plain, Iraqi Kurdistan. Modified map from Miglus *et al.* (2011), p. 139, Fig. 2

of the mountains. There are also al large number tells that dot the landscape, most of which are located on Pleistocene terraces.

Climate

The climate in the region is typically Mediterranean, with wet, cold winters and long, dry, hot summers. The mean temperatures range from 5°C in January to over 30°C in the summer (Ali 2007). However, the summer temperatures often exceed 40°C, as we experienced in 2011. Most of the precipitation falls during the period of November to March; and there is virtually no rainfall for five months of the year (Ali 2007). Unlike the area of Hirbemerdon Tepe, the annual precipitation rates are much higher here, averaging about 600 to 1000 mm a year, depending on the location in the basin area (Ali 2007). There is more rainfall in the Zagros proper than in the daghs and plains area (Ali 2007; p. 29, Fig. 2.7), resulting from their respective orographic positions. The average annual precipitation at Suleimaniyah station between 1941 to 2006 is 678 mm/year (Ali 2007; p. 24, Fig. 2.1), and rainfall varies, with more rainfall in the northeastern section of the plain (Ali 2007).

Figure 3.16: View of the hillsides, including terracing (right hand side) near the town of Zayway

Land use and vegetation

Because of the high annual precipitation rate in the region, dry farming is possible. In addition, the brown alluvial soils are very fertile. The area is known for its land fertility, and has been since antiquity (Mühl 2012), however, only about 30 per cent of the land is actually used for agriculture (Mühl 2012, Altaweel *et al.* 2012), which is mainly grain, but also includes sunflower and cotton (Ali 2007) and other crops; these are grown both in summer and winter.

Much of the region (some 50 per cent: Mühl 2012) is used for livestock grazing, including cattle, sheep and goat. This includes areas that would be impossible to farm (some of the slope areas which are covered in rocks for instance), but also areas which could be used for grain agriculture. According to Ali (2007), there has been an increase in livestock grazing, which places more pressure on the grasslands, woodland areas and soils through the threat of overgrazing.

Other crops are grown, such as vegetables, and small fruit orchards can be seen in plots in arable fields, as well as on the terraced hillsides (see Figure 3.16). The groves in the fields are often irrigated (water is mechanically pumped from groundwater supplies), but this is small scale. In the plains areas, there are areas of riparian gallery forests, with reed / sedge beds along parts of the Tanjero and

Figure 3.17: Animal herding and husbandry in the Shahrizor and surrounding areas and women collecting shauk in the springtime

other perennial streams.

In the hillsides and higher elevations, there are many wild flowers, as well as stands of various trees and shrubs. Oak, *Prunus* and various shrubs and wild fruit (including possibly wild grape: pers. comm. Prof. Dorian Fuller) have been observed by Prof Fuller, Dr Eleni Asouti and myself in various mountainous areas. Although there has been much deforestation in the region, the government is currently actively attempting to plant more trees in the highlands, mainly to combat the problem of accelerated erosion. These modern stands are recognisable, partly by tree age, but also because they are of similar height and usually are monocultural.

As well as agriculture and animal husbandry and herding, wild plants are collected (see Figure 3.17), particularly wild herbs and shauk, which are also sold in the local souk. However, much of the knowledge of wild plants seems to be declining, and as such there are now efforts by the government, Nature Iraq, the First Lady of Iraq (Mrs Hero Ibrahim Ahmed Talibani) and the Royal Botanical Garden at Edinburgh to preserve this knowledge of wild plants and to document the flora of this region (for the new *Flora of Iraq*: Laurent 2013).

There are also issues with regards to traditional pastoralism and agriculture: both are being negatively impacted (Laurent 2013). Pastoral and tenant villages (such as those documented by Barth 1953) are disappearing, and traditional crops, such as walnuts, melons and a species of rice (*Qush Qaya*) is waning (Laurent 2013). The Braidwoods, who excavated in the region in the 1950s (see below) describe an area which seems more diverse in terms of wild and cultivated plants: oleander, oak and other smaller trees along streams in Erbil and Suleimaniya provinces; many different cultivated plants including wheats, barley, tobacco, rice (possibly *Qush Qaya*), fruits, berries; and with the mountains covered in pine and oak stands, and meadows, with orchards, vineyards cultivation and woodcutting and charcoal making activities (Braidwood and Howe 1960). They also describe mobile tribes (including the Herbi) and the traditional flat-roofed mudbrick houses in the mountains (Braidwood and Howe 1960). Barth (1953) also mentions the Bedouin who, at least until the early 1950s, were grazing their camels in the Chemchemal, as well as nomadic Kurds, such as the Jaf.

Soils

The alluvial plains are characterised mainly by fertile 'brown' soils. These brown soils have been reclassified from Mollisols (Sehgal 1976), which are common in steppic environments such as these. The reason is that the soils are simply not the right colour (due to the presence of different iron levels and geochemical processes)– they are more red than brown (which was evident in many of the sections across the valley), and with a high $CaC0_2$ content, and are thus classified as Calcisols (using the World Reference Base for Soil Resources: Ali 2007) or Calcixerolls (Sehgal 1976). The reddish colour is indicative of its high iron context (see below). There are localised variations of course, with fluvosols (or alluvosols) in alluvial areas and Rendolls and Xerorthents on the mountain sides (Ali 2007, Sehgal 1976). In the uplands, the soils are thinner, however, some agriculture, particularly irrigated fruit groves, in the terraced areas (see Figure 3.16) is practised.

The soils are fairly deep in the basin: in the study area, the soil profile exceeds 1m (see Figure 3.18). It is also fairly well drained, and comprises mostly of silts (50-65 per cent), with 30 to 45 per cent clays and 5 to 10 per cent sands (Ali 2007). It is also described as being 'homogenous' (Ali 2007; p. 6). This is consistent with what was found in the cores, trenches and sections, not only for the soils themselves, but also for much of the underlying sediments and palaeosols as well, which are reworked Pleistocene soils (see below). Ali (2007) also notes that nearer rivers, the soils are more sandy. This was also noted around areas such as Yasin Tepe, and reflects weathered overbank deposits. The soils are

Figure 3.18: The dark top soil can be seen at the top of the section (from the Deep Trench, see Chapters 6 and 7). It exceeds 1 metre in the valleys, and thins out on the Pleistocene terraces and hill slopes. The reddish sediments below are reworked terra rossa soils

generally alkaline (7.5-8.2 pH) and are rich in calcium carbonates (Ali 2007). Geochemical analysis of samples taken from around the plain indicated that the soils had over 8.0 pH.

Terra rossa may also have been formed in the uplands, particularly in the Pleistocene interglacials. Terra rossa, a reddish soil which contains high amounts of sesquioxides, is common around the Near East, and composes much of the soils found in the lower alluvial plains areas (see Atalay 1997, Bronger and Bruhn-Lobin 1997; see Figure 3.18). The formation of terra rossa is still not clearly understood. It is most likely that the iron oxides in the terra rossa originate from Saharan dust (see for instance, Shapiro 2006, Merino and Banerjee 2008, Yaalon 1987). The Saharan desert is composed of sands which have a haematite coating (due to diagenesis), giving them a reddish appearance. Dust is lifted into the upper atmosphere, circulated around and deposited in areas such as the Near East, the Bahamas and Florida. The iron oxides are then incorporated into the limestone as it weathers into soil. However, the soil was initially formed, it is likely a main component of the sediments and soils found lower down in the valley – indeed in the deep trench, most of the sediments displayed a very red colour (see Chapters 6 and 7).

Geology

The mountains surrounding the plain display a wide variety of features, including folding, which attest to the tectonic influence in this region (see Figure 3.20).

The Shahrizor plain, which forms part of a series of plains including the Perimagroon, Chemchemal and Rania plains, lies within the Highly Folded Zone, which was created by the Arabian plate (oceanic) subducting under the Iranian (continental) plate, resulting in folding and eventually a thrust front (the daghs), a sub-foreland basin (the plain itself) and the orogenic wedge (the Zagros mountains) (see Karim *et al.* 2008, Ali 2007). This process of subduction and folding continued, uplifting the mountains and basin area above sea level. This is a typical subduction process and according to Karim *et al.* (2008), took place from the Middle Eocene through the Miocene. A similar process can be seen in the Hirbemerdon Tepe region, where the Arabian plate collides with the Anatolian plate.

The Shahrizor is bounded by the Bizard, Baranan and Qara Daghs to the west and south, which consist mainly of Cretateous and Eocene limestone (Eocene Pila Spi and Sinjar formations to the west and Cretaceous Balambo formation in the south), with some sandstones and marls (Ali 2007). On the east, the plain is bounded by the Zagros mountains proper, which in this area, mainly consist of Cretaceous (Balambo, Kometan and Qulqula formations) and Triassic (Avroman) limestones, with marls and sandstones (Ali 2007; see Figure 3.19).

Many of the hills and mountain facies are deformed – due to extreme tectonic activity, the beds were folded, creating the synclines and anticlines, now visible on the faces of the slopes (see Figure 3.20). These are mainly due southwest because of the 'stress of the overriding Iranian plate' (Ali 2007; p. 67). There is also a thrust fault that runs along the Zagros on the east side of the plain. This area is also known as the Western Zagros Fold-thrust Belt (Karim *et al.* 2008).

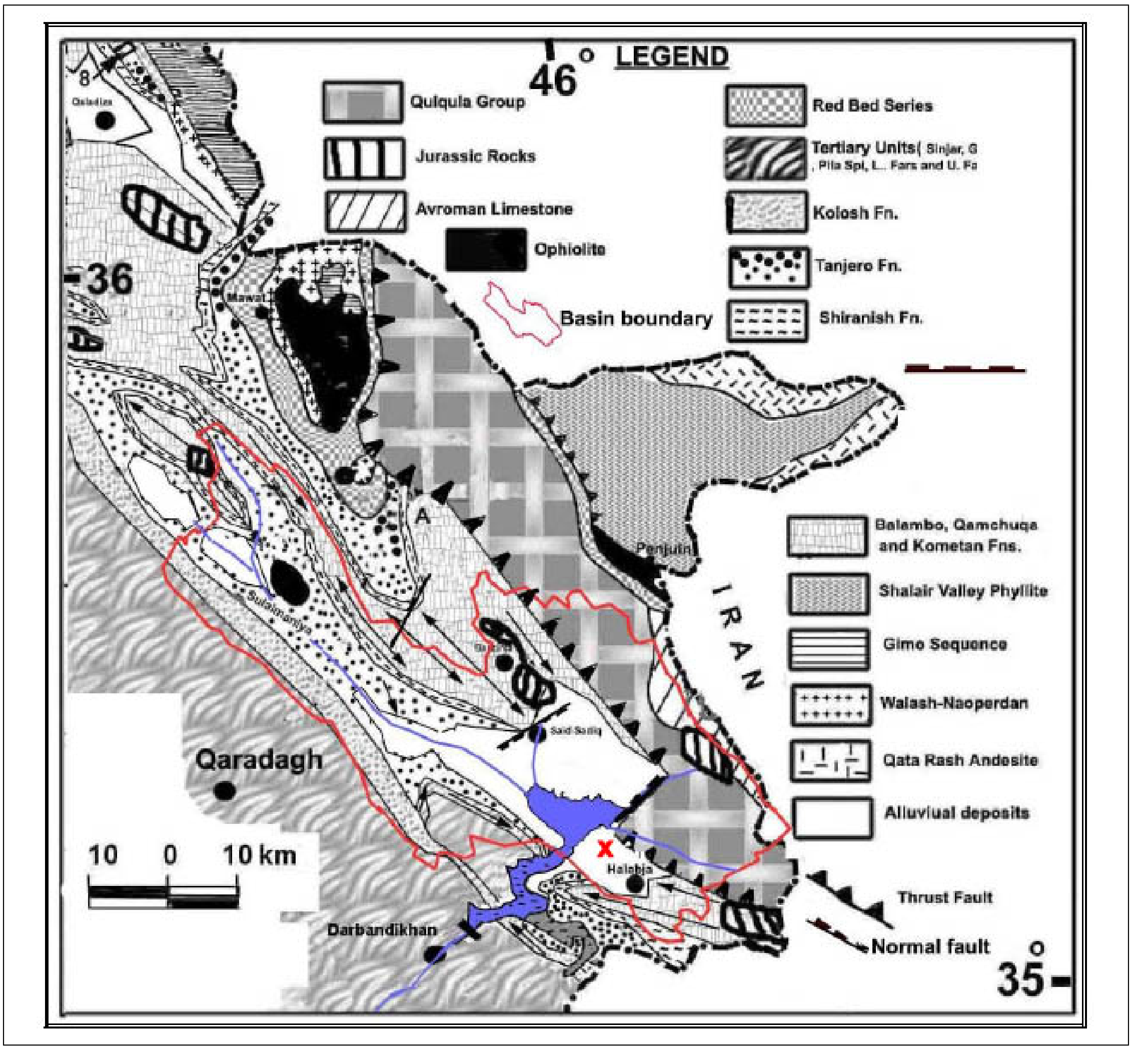

Figure 3.19: Geology of the region, the red x marks the approximate position of Bakr Awa. Map modified from Ali (2007), p. 69, Fig. 3.2

There are a lot of caves in the region, many are well-known to the older generations of the population as they used to hide, store weapons, etc, during the various periods of political instability and war. They were also used in the past to pen animals, possibly to store food stuff and for shelter.

Two of the caves explored with palaeoclimatologist, Prof David Mattey, Kuna Ba and Gejkar, were created by different processes: initially the folding of the strata created spaces between the beds, which were then later further weathered and eroded through karstification to create larger caverns (see also Stevanovic *et al.* 2009). These caves, and likely others in the region, contain large slabs of 'roof fall' on the floor of the cave. This is particularly the case of Kuna Ba, where these large slabs of limestone made getting through the cave very difficult. These caves, because they are limestone, also contain stalagmites

Figure 3.20: The distinctive folds of the rock shelters near Sa'id Sadeq

and stalactites, the former of which (speleothems) are very useful for climate studies (see Chapter 2).

Geomorphological processes

The main landscape formation in the very distant past was through tectonic activity, i.e., the uplift and folding of the limestone, sandstone and other sedimentary units during the Eocene and Miocene, the deposition and lithification of various sediments from the Triassic onwards and volcanic activity, particularly in the more northern areas of the Zagros mountains. This activity formed the structure, the backbone so to speak, of the region, creating the high mountains, and the flattish plain areas in the basin area and the daghs. Other geomorphological processes are now more prominent although tectonics still plays a minor role in the continued uplift and folding of the mountains. These processes include colluvial, alluvial, karstic and aeolian, caused by gravity, water and wind.

The sides of the hill slopes have been softened by sediments moving down the hills due to gravity and water action over the millennia. These processes include mass wasting and slumping – essentially sediments (muds to boulders and larger) sliding down the slope due to gravity and water saturation – as well as fans, sediments deposited at the foot of the slope by streams and gravity (see Figure 3.21).

Figure 3.21: The slopes near the town of Zayway have been softened through repeated episodes of erosion of sediments by gravity and water

Karstification is also a major process. Karstification occurs in environments where there is soluble geology (for instance limestone, gypsum and dolomite), and the presence of water. The water dissolves the soluble rock, creating features such as caves and sinkholes. Karstification is also responsible for the caprock dolines in the Hirbemerdon Tepe environs, as discussed above. However, Ali (2007) notes that these types of dolines are not as common in this region.

Fluvial processes are very important in this region and are not only active in the mountains, which are highly incised, indicating past and present stream channels, but also in the plain itself. Both erosional and depositional processes take place. There are many terraces in the plain, dating to the Pleistocene and Holocene. Many of the Pleistocene terraces appear as low hills, and are made mostly of gravels and are excavated now by building companies. Some of the Pleistocene terraces are buried under later Holocene alluvial sediments. Much of the Pleistocene deposits have been eroded away due to repeated cycles of channel cutting in the Holocene. The Pleistocene terrace hills represent those areas not as impacted by this fluvial erosion. The Holocene terraces are more difficult to detect, other than by coring and sections, because many of the earlier terraces are covered by later sedimentation.

Sedimentation is heavy in the region, partly because of the increased erosion due to lack of hillside vegetation. However, as will be discussed in Chapters 6

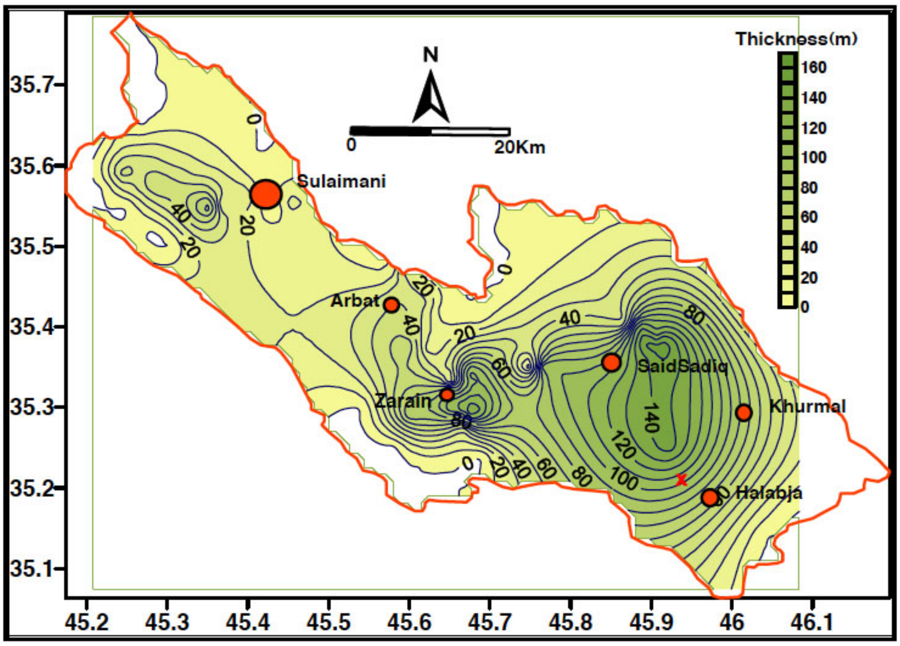

Figure 3.22: An isopach map of Quaternary alluvial sedimentation in the area, the red x indicates the approximate location of Bakr Awa. Map modified from Ali (2007), p. 88, Fig. 3.21

and 7, heavy sedimentation and stream channel activity seems to be characteristic in this area. In the Bakr Awa area, the cores and the trench reached 6-7 meters before hitting Pleistocene gravels (see Chapter 6). There may indeed be areas where the Holocene sediments are closer to 9 metres. Overall sedimentation, including that of the Pleistocene, can reach up to 140 metres (Ali 2007; p. 88, Fig. 3.21; see Figure 3.22).

The site of Bakr Awa sits on a Pleistocene terrace and although the sides look fairly steep, parts of it have been severely eroded by wadi cuts. The sides are steep, too steep for tell of this age, however it is likely that the sides were reinforced, perhaps during the Islamic period (M Altaweel, pers. comm.). On either side of the site, particularly where the lower town is located, there is severe erosion by two wadi channels which have cut into those areas and somewhat into the sides of the tell proper (see Figure 3.23).

There was also damage inflicted by the Iranian army who built structures on top of the tell during the Iran Iraq war, as well as holes left by looters, especially in the lower areas.

Sedimentation is also caused by aeolian processes. Sometimes, especially in the fall when the ground is brown and the fields have been harvested, the Za-

Figure 3.23: One of the wadi channels cutting into the site of Bakr Awa; the main part of the tell is to the right

gros and Daghs are hard to see when the dust is being blown around. However, these aeolian processes are considered to play a minor role in the geomorphology of the regions (Ali 2007) and are probably more prevalent in modern times due to increased agriculture, grazing and habitation and reduced vegetation.

3.2.2 Regional context

The survey work carried out by Dr Mühl in the Shahrizor area has added to the number of known sites in the region (recorded in the ASI and AASI; see Figure 3.24). Thirty sites were surveyed between 2009 and 2011, and of these sixteen were previously unrecorded. The surveyed sites date from the Neolithic to the Islamic periods, and many are multiperiod (Altaweel *et al.* 2012). Bestansur, which lies north of the Darband-i Khan dam lake (no. 6 in Figure 3.24) contained the earliest period pottery sherds and lithics, which are similar to those found in early levels at Jarmo (Altaweel *et al.* 2012). Six other Neolithic sites were also surveyed and the Ubaid period was represented by eleven sites, with twelve sites for the Late Chalcolithic – many of the Ubaid sites continue into the Late Chalcolithic (Altaweel *et al.* 2012). However, Hassuna and Halaf are both underrepresented in the region (see below). Prof. Karen Radner (UCL) has studied texts (mostly from southern and northern Mesopotamia) to better understand the history of the region as recorded in the cuneiform texts (Radner 2014).

The area of the Shahrizor plain and its environs has been inhabited since

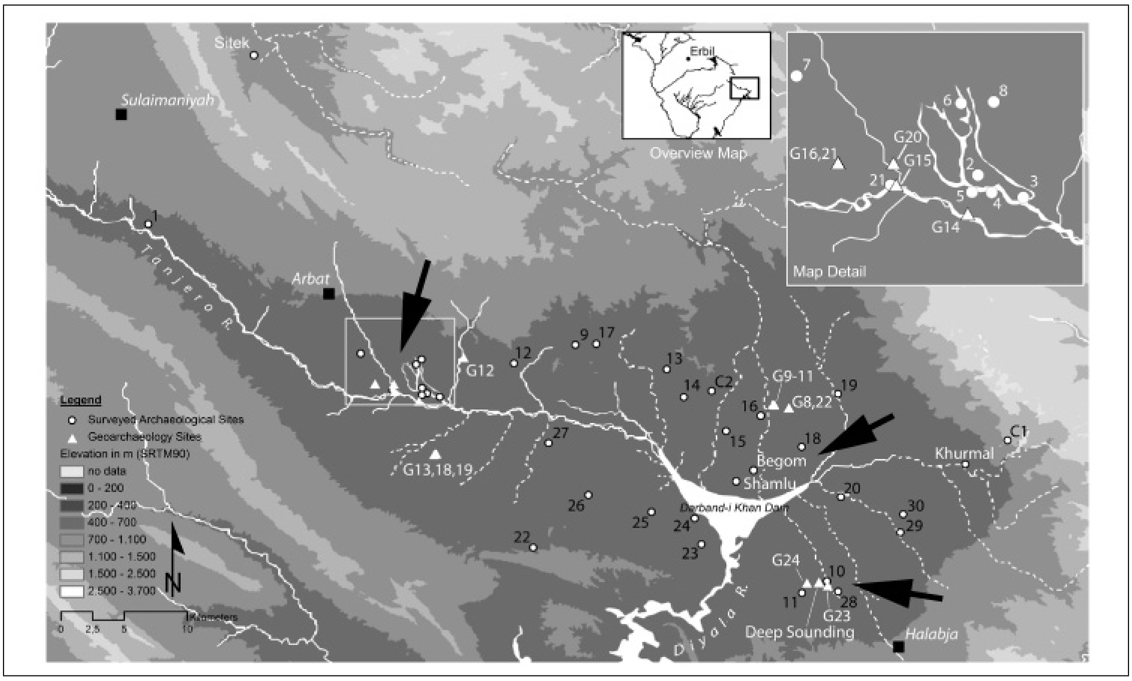

Figure 3.24: Archaeological and geoarchaeological survey areas/sites in the Shahrizor. 1. Tepe Kal, 2. Yasin Tepe, 3 Marif Tepe, 4. SSP 4, 5. SSP 5, 6. Bestansur, 7. Girda Resh Barika, 8. Kazaw, 9. Greza, 10. Bakr Awa, 11. Gurga Chiya, 12. Bin Gird-i Muan, 13. Gird-i Saraw, 14. Gird-i Qalrakh, 15. Gird-i Shatwan, 16. Tell Hajji Abdallah, 17. Quruchiya, 18. Gird-i Qara Tepe and Gird-i Sharif, 19. Gird-i Qulkhurd, 20. Lamarkazi, 21. Kara Gol, 22. Qalija, 23. Sutik Tepe, 24. Gird-i Shakar, 25. Qalbaza Tepe, 26. Alan Tepe, 27. Maluan, 28. SSP 28, 29. Tepe Kurra and 30. Tepe Sheshak Hagg Hussain. C1. Khan Ahmed Khan Cave and C2. Said Sadeq Cave. The geoarchaeological survey areas are discussed are indicated by arrows and discussed in Chapters 5 and 6. Map modified from Altaweel *et al.* (2012), p. 2, Fig. 1

the Palaeolithic. There are numerous cave sites, including Shanidar cave, and Ishkaft Palegawra and Ishkaft Barak in the Erbil area (the last two are rock shelters: Braidwood and Howe 1960), and Khan Ahmed Khan Cave near Khourmal and Sa'id Sadeq (C1 and C2 respectively on Figure 3.24), with Upper Palaeolithic finds. These sites all attest to this early, albeit not continuous, habitation during the Pleistocene. When these cave sites were inhabited is not clearly understood, and is very dependent on the effect of localised glaciation during the ice ages.

During the Early Holocene, settlement became more sedentary in the region and early sites, such as Jarmo (dating to *circa* 7000BC) are attested in the region. Exactly when domestication and a more sedentary way of life occurred in this region is still under investigation.

In the Shahrizor itself, Neolithic sites (Halaf and Hassuna) are not particularly well represented, at least in the survey work and excavations done thus far. This is most likely due to the nature of settlement in the region: many of the sites in the region are multi-period and thus later settlements may be obscuring the evidence of earlier settlements, particularly when looking for field scatters (Altaweel *et al.* 2012). In addition, there is evidence from Northern Mesopotamia that there was a shift to semi-pastoralism around 6200BC and thus sites during this period were not especially long lived and would be harder to detect archaeologically (Altaweel *et al.* 2012).

Geomorphological processes may also have had an impact on the preservation and visibility of these sites. Single-period sites will have smaller tells: tells are created through the continuous cycles of construction and deconstruction over a relatively small area. If a site was occupied for only a short period, and it is not reoccupied at some later point, the tell will be smaller to begin with, and furthermore, older sites, i.e., Neolithic sites, will have eroded more until they become flattened (see for more detail: Rosen 1986). In addition, ploughing would also accelerate the erosion of these small tells.

Sedimentation can also be very deep in some parts of the plain, as evidenced by the offsite trench we excavated near Bakr Awa. If sites were situated near a river (i.e., in the alluvial plain), rather than on a Pleistocene terrace, it is likely to have been buried under metres of sediments by subsequent alluviation episodes, thus rendering the site invisible, especially in a survey (see also Altaweel *et al.* 2012).

In any case, there are Neolithic sites in the plain. The earliest site, dating possibly to the Pre-Pottery Neolithic (PPN), is Bestansur, and flint tools, similar to those found at Jarmo, as well as Neolithic sherds, were found (Altaweel *et al.* 2012). Pottery Neolithic sites have also been recorded in the plain, including Qara Gol, Bestansur, Gird-i Shakar, Gird-i Qulkhurd (see Figure 3.24 Altaweel *et al.* 2012), and Halaf sites as well at Tell Begum and Tell Sragon (Hijara 1997, Altaweel *et al.* 2012).

UCL has just begun excavations at a site called Tepe Murani, located close to Gurga Chiya, and about 1.5km from Bakr Awa. It is a low tell, which lies in an agricultural field and so has been ploughed extensively. However, although much material was found in the plough zone, beneath this were *in situ* remains from a Halaf site, including painted pottery and a possible structure (possibly a 'round house'), which will be excavated more extensively next season (Prof Dorian Fuller, pers. comm.). What this shows is that more Halaf sites could be found in the agricultural plains areas, and very difficult to detect as they are also low lying and have been damaged due to ploughing activity. However, there is still potential for good preservation under the plough zone.

In the wider region, later Neolithic periods are better represented. Hassuna period is attested at Tell Matarra (Kirkuk), Tell al Khan (on the Erbil-Mosul road) and Qalat Jarmo (Chemchemal) (Braidwood and Howe 1960), as well as Shemshara (Rania plain, northeast of Suleimaniya) (Mortensen 1970, Altaweel *et al.* 2012) and other areas. Halaf is attested at Gird Banhulk (Diyana near Ruwanduz) (Braidwood and Howe 1960).

The Chalcolithic period is better represented in the plain and eleven sites in the Shahrizor yielded Ubaid pottery (Altaweel *et al.* 2012), including Gurga Chiya (Prof Dorian Fuller, pers. comm.). There may also be Chalcolithic settlement at Bakr Awa (Miglus *et al.* 2013). The Chalcolithic is more archaeologically visible and this may be partly due to settlements becoming more permanent as people turned increasingly to agriculture (Altaweel *et al.* 2012). Many of these sites continued into the late Chalcolithic and new sites were also founded at this time (Altaweel *et al.* 2012). Uruk ware was also found at several sites, including bevelled rims excavated at Gurga Chiya, possibly indicating early trade links with southern Mesopotamia (Altaweel *et al.* 2012; Prof Dorian Fuller, pers. comm.).

The first half of the third millennium is virtually non-existent so far in this region. Again the above reasons for the invisibility of certain periods holds here: sedimentation may be burying some sites, while later settlement may be covering earlier sites. It is unlikely that there was no settlement in this region during this period. Early third millennium sites have been found along the piedmont area as well as in the Diyala region (Altaweel *et al.* 2012). These include Tall al-Namul and Tall al Faras, Kirkuk and others along the Lesser and Greater Zabs and the Tigris (Mühl 2012). There may also be some settlement at Bakr Awa at this time (Miglus *et al.* 2013).

At the end of the third millennium, there is more information in the form of written documents, which helps to gain a somewhat better understanding of trade networks and links between different areas and an idea of possible sites in the plain.

From *circa* 24th to 18th centuries BC, according to the available textual evidence, the Kingdom of Simurrum flourished, with its capital most likely in the Shahrizor plain (Altaweel *et al.* 2012). It represents one of the most long lived and 'stable entities' in the Near East (Altaweel *et al.* 2012; p. 10).

The Akkadian sources, gives a name for a ruler of Sumurrum, Baba, and states that Simurrum was an enemy of the Akkadian Empire (Altaweel *et al.* 2012). Interestingly, there is a Hurrian link here, as with southeastern Anatolia: the name of a battle place as mentioned in a text dating to the reign of Naram-Sin, is Kiraseniwe; however, the etymology of Baba's name is unknown (Altaweel *et al.* 2012). Sumurrum is also mentioned as an enemy of the Gutians, specifically the king, Erridu-pizir; another Sumurrum ruler (this time called a 'king') is also named: Nisba (Altaweel *et al.* 2012). KA-Nisba is also named as ruling over Lullubum, an area encompassing parts of the Transtigris region (Mühl 2012). During Ur III, Sumurrum is annexed; it was then under the rule of Tappan-Parah (a Hurrian name), and was allied with Urbilum (Erbil), Lullubum and Karakina (Altaweel *et al.* 2012). After a short period, Sumurrum regains its independence and is allied with Ur, and then an enemy again; and finally becomes allied with Isin, after the fall of Ur (Altaweel *et al.* 2012).

Archaeologically, Sumurrum is attested in rock reliefs and stele, but not so well in survey and excavation finds. There are rock reliefs and stele were near the Rania plain and at Sar-i Pola-i (located in the peidmont area southwest of the Diyala) and rock reliefs at Zeriya in the Pirmagroon and Darnad-i Gawr in the Qara Dagh mountains (both located in the Shahrizor proper) (Altaweel *et al.* 2012). Late third millennium finds were rare in survey and come from mostly the southeastern part of the plain, with one exception: Marif Tepe in the north, which had Akkadian ware (Altaweel *et al.* 2012). Bakr Awa also contains late third millennium levels, but these have not been extensively excavated as yet (see below).

As discussed above, the Hurrians may have either originated from the Taurus region or the Zagros mountains. It is interesting that some of the rulers and court officials of Sumurrum have Hurrian names. However, others also have Akkadian or etymologically unknown names (Altaweel *et al.* 2012). There is certainly a Hurrian link here as well as in Anatolia, but it seems that this region may have been more a crossroads rather than a Hurrian state proper.

At the beginning of the Old Babylonian period, Sumurrum seems to be waning. Initially, in the Shahrizor (Bakr Awa) and sites from adjacent regions (Shemshara in the Rania plain and Basmusian) indicate links with the Hamrin mountains (piedmont area near the Tigris) (Altaweel *et al.* 2012, Miglus *et al.* 2011). Then there is a complete change to a different pottery style, Shamlu ware, found first at Tell Shamlu (Janabi 1961). This may be linked to political events and upheaval further afield. In 1781BC, there was a battle between Dadusa of Esnunna and Samsi-Addu of Ekallalum (Altaweel *et al.* 2012, Eidem 1985). This seems to have been a period of upheaval, and Sumurrum apparently is no longer the powerful centre it once was. There do not seem to be any parallels to Shamlu ware outside the Shahrizor (Altaweel *et al.* 2012). Shamlu ware was found at 15 sites in the Shahrizor (Altaweel *et al.* 2012; see Figure 3.25). Single sherds were found at Shemshara (Rania) and Yorgan Tepe (Nuzi).

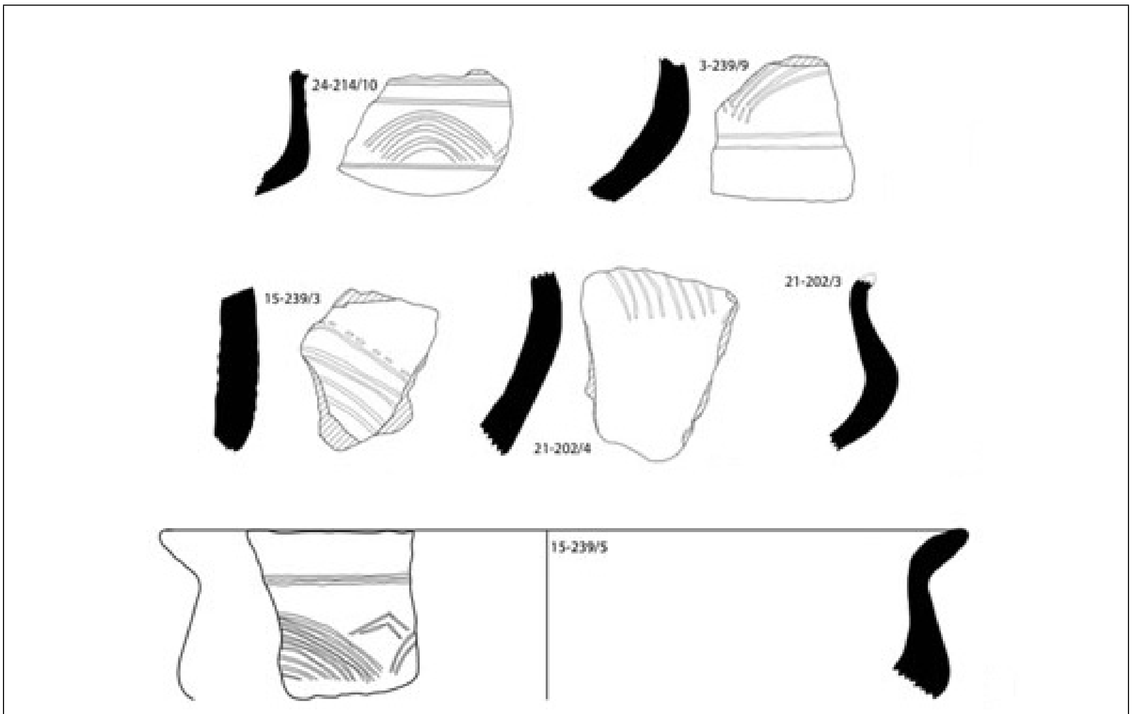

Figure 3.25: Examples of Shamlu ware found during the Shahrizor survey. Image modified from Altaweel *et al.* (2012), p. 26, Fig. 14

Textual sources indicate that in the late second millennium, the Shahrizor became part of the Kassite (southern Mesopotamian) kingdom, Karandunias (Altaweel *et al.* 2012). The survey evidence indicates Kassite pottery, as well as knobbed beakers, which in turn points to contacts with south and north Mesopotamia and Hamrin (Altaweel *et al.* 2012). However, there is another pottery type, which is locally made, with possible influences from Iran (Mühl 2012), indicating that this region, although no longer a powerhouse, is still connected to different parts of the ancient Near East. In the 12th century, the Kassites and Assyrians (in the north) had signed a treaty establishing their respective territories; Shahrizor was to be under Kassite control (Altaweel *et al.* 2012). By the 11th century, this treaty was seemingly no longer valid (Altaweel *et al.* 2012).

By the 10th century, the Shahrizor and surrounding regions is known as Mazamua and is made up of independent entities, one of which was located in the Shahrizor (Atlila, which has been identified with Bakr Awa: Altaweel *et al.* 2012). The Assyrians repeatedly attempted to control this region and finally succeeded in 842BC and held on to it until the late 7th century BC (Altaweel *et al.* 2012). After the upheaval, it became part of the Neobabylonian empire (Altaweel *et al.* 2012).

Archaeologically, this period is attested by Neoassyrian and Neobabylonian assemblages from several survey sites; there are also assemblages deriving from the Iranian Zagros.

There is continued settlement, as seen in text sources, survey and excavation, from the subsequent Achaemenid, Parthian, Sassanian and Islamic periods, attesting to the continued importance of this region as a crossroads between Mesopotamia, the Transtigris region and Iran.

Due to the political unrest in the region over the last few decades, Iraqi Kurdistan is a very understudied part of the Near East. However, with the recent stability and renewed interest in the area, this is changing rapidly, with many excavations currently underway at Bakr Awa, Gurga Chiya, Tepe Murani and Bestansur in the Shahrizor plain (see Figure 3.24), Jarmo in the Chemchemal region and a number of sites in the Erbil province (this may all change again, unfortunately, due to the situation with the so-called Islamic State). In the 1950s, the Oriental Institute of University of Chicago initiated excavation in the region, under the directorship of Braidwood, mainly in the Chemchemal region (see Braidwood and Howe 1960, Braidwood 1983). Sites included Jarmo and Karim Shahir (in the Chemchemal), and Upper Palaeolithic and Neolithic sites near Erbil, Mosul and Kirkuk (Braidwood and Howe 1960, Braidwood 1983). The project was multidisciplinary and involved geologist HE Wright, botanist H Helbaek, and zoologists F Barth and CA Reed. Barth left the project to pursue an ethnographic study of the region (Barth 1953, Braidwood 1983).

After the Braidwoods left in the 1950s, little was done by Western archaeologists. There were some surveys and excavations by the Iraqi Directorate of Antiquities and Heritage, especially with regards to those sites threatened by the various damming projects, including the construction of the Darband-i Khan dam in the 1960s and subsequent lake in the middle of the Shahrizor (see Figure 3.24). In the 1940s, the Directorate initiated a project to survey all known sites in Iraq, including the Shahrizor plain. These are now published in Archaeological Sites in Iraq (ASI) and the Atlas of Archaeological Sites in Iraq (AASI) (Altaweel *et al.* 2012). Some of the sites excavated and published included Bakr Awa (see below) and Tell Shamlu (Janabi 1961). Other sites were also excavated, including Tell Bagum, Tell Qortas, Tholima and others, but not published very extensively (Altaweel *et al.* 2012). Excavations were sporadic and not particularly well published, and due to the instability of the region, not much was done to better understand the settlement history of the region.

After 2003, the Directorate of Antiquities and Heritage in Suleimaniyah initiated more excavations in the Shahrizor, including Arbat, Tanjero and Greza; as well as at sites in nearby districts (Altaweel *et al.* 2012).

In 2009, Dr Simone Mühl and a University of Heidelberg team under the directorship of Dr Peter Miglus obtained permissions to survey the region and to excavate at Tell Bakr Awa respectively. In 2010, a team from UCL, including Prof Karen Radner and Dr Mark Altaweel joined the project, and I joined the team in 2011. Since then, new excavations have been initiated by various teams from various universities, including University College London.

Figure 3.26: Bakr Awa, about 400 metres due south

3.2.3 Bakr Awa

Tell Bakr Awa is a multi-period (Late Uruk to Islamic periods) site lying on top of a Pleistocene terrace (see Figure 3.26). It encompasses the tell area proper as well as a lower town found in the lower lying areas of a Pleistocene terrace. The tell is very large (measuring circa 40m high, 300m in diameter and *circa* 40 hectares; the lower town is about 800 x 600m: Miglus *et al.* 2011), and is a prominent feature on the landscape, not least because its sides are still very straight.

Bakr Awa was initially excavated in 1960-1 by the Iraqi Directorate of Antiquities and Heritage as part of the Darband-i Khan salvage project. A sounding on the slope of the mound (see Figure 3.27) contained layers from the Islamic to the early second millennium (and possibly earlier) periods: seven Islamic, three Hurrian, five Old Babylonian / Isin Larsa (Miglus *et al.* 2011). Ur II and Akkadian layers were also apparently excavated (Miglus *et al.* 2011). Unfortunately, only the Islamic period material was published (Altaweel *et al.* 2012, Husaini 1962, Madhloom 1965). A second trench was opened in the lower town area, with Islamic, Iron Age and second millennium layers (Miglus *et al.* 2011). In addition, about twenty cuneiform tablets were found in second millennium contexts (Miglus *et al.* 2011). At the lowest level, a large building was excavated, which was initially interpreted as an Old Babylonian temple (Miglus *et al.* 2011). It has now been reinterpreted as a private house (Miglus *et al.* 2011; 2013). Al-Soof published Late Chalcolithic (Uruk) material from the second season (Altaweel *et al.* 2012, Soof 1964), but no context was given (Miglus *et al.* 2011).

Figure 3.27: Remnants of the sounding from the 1960-1 Iraqi Directorate of Antiquities and Heritage excavations, which were part of the Darband-i Khan salvage project. Top of the citadel, looking north

Figure 3.28: Trench from 2011 season exposing third millennium levels, including a possible Akkadian shrine room (see Chapter 7). Lower town, looking north

In 2009, Peter Miglus and Simone Mühl initiated a survey of Bakr Awa, which was followed in 2010 by excavations in the lower town area. In 2011, another trench was opened on the mound itself. The survey data backed up earlier Iraqi finds of long occupation on the site (taking Soof's finds into account), from the Uruk into the Islamic period (Miglus *et al.* 2011; 2013). The recent excavations also support this.

The first trench in the lower town uncovered Islamic, Iron Age and Middle Bronze Age levels (Miglus *et al.* 2011). A second trench, connecting to the original Iraqi trench, was also opened, and included layers form the Islamic, Iron Age, Late Bronze Age, Middle Bronze Age and Early Bronze Age levels.

The Iron Age finds were not extensive, but although the pottery was locally made, there appears to be influence from the Northern Tigris (piedmont) and Iran (Miglus *et al.* 2011), corresponding with the survey evidence. The pottery from the LBA reflects a northern Mesopotamian influence (Miglus *et al.* 2011). The MBA is best represented, and seems to be the time when Bakr Awa flourished (Miglus *et al.* 2011). Third millennium levels have been exposed including, in 2012, an Akkadian shrine, but are only now beginning to be examined (see Figure 3.28).

Part II

Theory and methods

Chapter 4

Constructing landscapes: environmental change and human agency

4.1 Introduction

As discussed in Chapter 2, there are many issues which arise when using environmental data and archaeological data together, which include dating and synchroneity. Another issue is the dichotomy between the biophysical and social sciences, particularly in reference to theoretical frameworks. This is evident in Near Eastern archaeology where there has been much research on both environmental and sociopolitical change. However, the environment is frequently treated as a passive backdrop to active political processes. In other cases, the sociopolitical, economic and technological aspects are marginalised and cultural changes are attributed exclusively to climate or environmental change (for instance, Weiss *et al.* 1993, Burroughs 2005).

It is, however, difficult to merge the two sides. The language is different and scales (temporal and spatial) can be different, as was discussed in Chapter 2. These differences can be overcome, but there is another issue: the lack of communication between the two (Hornborg 2007).

Attempts to bridge the gap between the two sciences include: cultural ecology (see Butzer 1982, Steward 1955) and to some extent cultural materialism

(Harris 2001a;b). Both try to combine the roles of society (culture) and nature (the environment) in various historical processes. However, they only consider societal adaptation to the environment and environmental change, rather than how societies change their environment. Political ecology, which was meant to 'integrate human dimensions and biophysical factors' (Stonich and Mandell 2007; p. 266), was another attempt. Unfortunately, it has become too focused on modern environmental issues and it is difficult to understand how it can be applied to past societies and ecologies. As Stonich and Mandell (2007; p. 265) point out, political ecology seems to be becoming more like 'environmental politics' and lacks ecology (for example, Third World political ecology, see Bryant and Bailey 1997, Bryant 1992).

More recently, Hornborg and Crumley (2007) re-addressed this dichotomy between the social and biophysical sciences, demonstrating again the need for a common language and communication. Hornborg (2007; p. 1) argues that the best way forward is to adopt a more systems-orientated approach as a way to 'transcend' the division, in essence, using systems theory to answer questions about humans and the environment and all of the socio-political, economic, technological and 'natural' complexity that this entails.

This is an approach Butzer (1982) no doubt agrees with as cultural ecology sees nature and humans as part of a system. While this systems approach is useful, again it is too focused on how humans adapt to the environment (either in equilibrium or disequilibrium), without consideration of how humans change the environment themselves and how this then feeds into the feedback loops.

This thesis examines the relationship between humans and their environment using environmental evidence combined with cultural material evidence. The theoretical framework approach is niche construction theory (NCT), with an emphasis on cultural niche construction theory (CNCT), in order to understand how societies may have changed their environments through niche constructing activities, how these modifications may have led to further niche construction by subsequent generations, and in what ways these modifications affected different aspects (biotic and abiotic) of the environment (using tenets from Earth systems science). Two elements of NCT, ecological and cultural inheritance, are explored as ways to understand how one generation passes on a modified environment and knowledge of that environment to the next generation.

4.2 Taming the environment: cultural niche construction and resource management

4.2.1 Niche construction theory (NCT)

Introduction

Humans are active agents of change. They construct habitats, which then in turn impact other aspects of the environment (hydrology, ecology, microclimates), societies, and in some cases, even the gene pool.

Niche construction theory, which was first developed in the 1980s by evolutionary biologists, posits that organisms modify their environments, 'thereby influenc[ing] their own and other species' evolution' (Kendal *et al.* 2011; p. 785). Organisms modify their environments in a number of ways.

One interesting example is that of the leaf cutter ant (*Atta* genus), which is found in the Americas (Odling-Smee *et al.* 2003). These ants are capable of creating large multi-chambered underground nests, in which they cultivate fungi on leaves cut from nearby trees. This leaf cutting is so extensive that several species are considered pests as the leaf cutting activity can have a severe impact on crops nearby (Odling-Smee *et al.* 2003). On the other hand, there are also benefits of their activities in terms of aeration of and circulation within soils; they may even be helpful in the reestablishment of forests after logging and farming activities (human niche construction): the softness of their nests make it easier for seedlings to take root and grow (Odling-Smee *et al.* 2003).

NCT describes the evolutionary process as being two-fold: driven by both natural selection and by how organisms modify their environments and selective pressures therein. In other words, organisms do not only adapt (via natural selection) to the extant environment, but also play an active role in their (and other species') evolution (Laland and Brown 2006). In traditional evolutionary theory, organisms are affected by the environment, but the environment is considered unaffected by organisms (Odling-Smee *et al.* 2003).

The evolutionary consequences of niche construction can be played out in four different ways: ecosystem engineering, modification of 'selective environments', ecological inheritance and adaptations based on both natural selection and niche construction (Odling-Smee *et al.* 2003; p. 3).

Ecosystem engineering is a term developed by ecosystems ecologists, who recognised that organisms alter their environments (and consequently that of other organisms) by affecting 'energy and matter flows' (Odling-Smee *et al.* 2003; p. 6). To put it simply, organisms can change their environments through repeated actions of using the same resources and leaving the same deposits (Odling-Smee *et al.* 2003).

The 'modification of selective pressures' is a result of ecosystem engineering. As Odling-Smee *et al.* (2003) point out, if an organism modifies its environment, then it follows that it may be affecting selection pressures as well, thus making it more likely to survive. However, this process must continue over the long term in order to be reflected in a more evolutionary scale: this is one aspect of the 'persistence criteria' (Odling-Smee *et al.* 2003; p. 9).

Ecological inheritance is the 'second general inheritance system in evolution' (Odling-Smee *et al.* 2003; p. 13), the first being genetic inheritance and the third being cultural inheritance (see below). However, in this case, instead of evolutionary changes being driven / inherited genetically (i.e., from parent to offspring), they are inherited through the environment. Offspring inherit the modified environment. It can best be compared to the inheritance of property or territory (Odling-Smee *et al.* 2003). This is also another aspect of the persistence criteria (Odling-Smee *et al.* 2003).

And finally, adaptation, which should be considered a more active process, and one where there is a feedback loop between organism and environment. Organisms do not simply respond and adapt to changes in the environment – they make changes themselves to that environment (Odling-Smee *et al.* 2003). In other words, they adapt the environment itself to suit their needs.

	Perturbation	Relocation
Inceptive	Modification of the environment is initiated by the organism	Modification of the environment is initiated by the organisms in a new locale
Counteractive	Organisms respond to change in the environment through further modification (niche constructing activities)	Organisms respond to change in their environment by moving to new one

Figure 4.1: The different categories of niche construction. Redrawn from O'Brien and Laland (2012), p. 440, Fig. 1

There are four different ways organisms can modify their environments: inceptive perturbation, inceptive relocation, counteractive perturbation and counteractive relocation (Odling-Smee *et al.* 2003, O'Brien and Laland 2012, Wollstonecroft 2011; see Figure 4.1). In inceptive perturbation and relocation, the change in the environment is initiated by an organism, either *in situ* or in a new area (Laland *et al.* 2010, Odling-Smee *et al.* 2003). Counteractive perturbation or relocation is a response to a change in the environment, including prior niche construction (Laland *et al.* 2010, Odling-Smee *et al.* 2003). It can be seen as a buffering strategy against change in order to maintain the *status quo* (Laland *et al.* 2010). These responses may be mainly cultural in human societies, rather than genetic, as will be seen below.

4.2.2 Cultural niche construction (CNC)

Organisms can react to (and consequently drive) environmental change through counteractive perturbation or relocation. They can also drive environmental change, at varying scales, through inceptive perturbation or relocation. As such, there is a feedback loop between the environment and organisms. Humans are no exception. Humans do not just react to environmental change, but they are also drivers of environmental change, and this will have an impact on both the environment and humans (and their cultures).

NCT is an excellent framework in which to investigate this feedback loop. As Laland and O'Brien (2010; p. 313) succinctly state: '...rather than slipping into the assumption that the external environment (e.g., climate change) triggers an evolutionary or cultural response, NCT enthusiasts are from the outset inclined to consider those additional hypotheses stressing self-constructed (and other organism-constructed) conditions that instigate change'.

Humans can be considered the 'ultimate niche constructors' (Odling-Smee *et al.* 2003; p. 28). Humans inhabit a diverse range of environments. They are able to do this not because they simply adapt to preexisting environments, but rather because they actively modify environments to suit their needs, and pass both knowledge and modified landscapes to the next generation.

Two 'inheritances' in evolution were discussed briefly above, that of ecological and genetic inheritances. There is a third mode of inheritance, which is particularly important when discussing human societies: cultural inheritance (see Odling-Smee *et al.* 2003). Cultural inheritance is the transmission of information (such as practices, skills, beliefs/rituals and knowledge) that is passed to succeeding generations through 'teaching, imitation and other forms of social learning' (Laland *et al.* 2010; p. 138).

Cultural niche construction, then, is the 'human ability to modify evolutionary selection pressures through innovation, learning, material culture and the cultural transmission of knowledge' (Wollstonecroft 2011; p. 144).

Odling-Smee *et al.* (2003; p. 249) argue 'that in the last 25 to 40 thousand years the dominant mode of human evolution has been purely cultural'. Laland *et al.* (2010; p. 140) further this by stating that 'human niche construction is informed by a uniquely potent and cumulative cultural knowledge base'. Cultural niche construction is essentially a more immediate solution (as opposed to a genetic modification, for instance) to whatever issues previous niche construction or change has incurred. This would fall under counteractive perturbation: buffering against change in order to maintain the *status quo* (or equilibrium) (Laland *et al.* 2010).

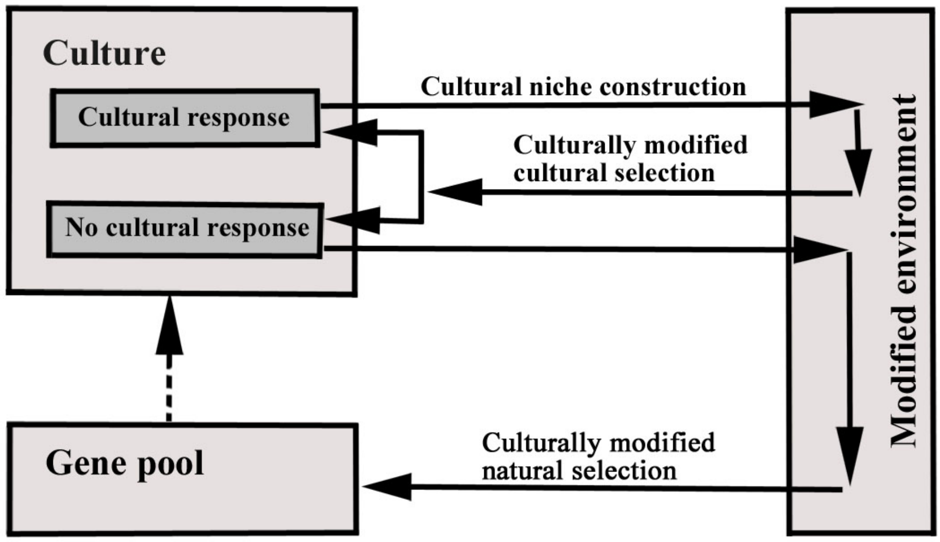

Figure 4.2: The environment may be modified by cultural niche construction activities. This is turn may lead to further cultural niche constructing activities, or there may be no response. If there is no response, this may (eventually) lead to genetic change, via 'culturally modified natural selection'. Redrawn from Odling-Smee *et al.* (2003), p. 262, Fig. 6.3

In some cases, there is a genetic result of cultural niche construction. For instance, the domestication of cattle and consumption of unprocessed milk products led to the selection of a particular gene that allows the synthesis of the lactase enzyme in adult humans (Odling-Smee *et al.* 2003). However, in most cases, responses to prior niche construction are cultural, and may not lead to genetic change (Odling-Smee *et al.* 2003, Laland and O'Brien 2011), at least not in the shorter term (see Figure 4.2). The fact that cultural niche construction is so dominant in human niche construction may help to elucidate why there seems to be a 'lack of correspondence between human allele frequencies and selective environments' (Laland *et al.* 2010; p. 141).

It has been argued by Riede (2011; p. 794) that 'culture ... constitutes the human niche, and environmental archaeologists have made human niche modification and its consequences their primary concern. This includes the domestication of animals and plants, as well as "domesticated landscapes", and even "transported landscapes".' As Laland and O'Brien (2010; p. 305) state, humans modifying their environment is not 'news', but the understanding of the 'ramifications' of these changes is. Although many environmental archaeologists still seem concerned with how humans have reacted to change in the past, there are many who seem to appreciate that human modification has implications that are certainly worth investigating and seem to touch on ideas of cultural and ecological inheritance (see for instance, Yen 1989, Balée 1998a, Erickson and Balée 2006).

Cultural niche construction theory provides a framework for investigating changing environments, cultural change and the feedback loops between them. It is also important to understand the properties and processes of environmental change and how human societies cope with them and manage their resources.

4.2.3 Earth system science (ESS)

Understanding the ecological inheritance is best approached using a systems-based perspective. Each modification sets off a chain reaction which feeds back into the other niches, leading to further niche construction and leading to changes in the other, abiotic, aspects of the environment (soils, hydrology, atmosphere, etc). ESS helps us to understand how, the mechanics, of modification. Changes such as deforestation, for example, impact fluvial systems by changing the water budget and increasing the potential for erosion, thus modifying the environment. Here the systems approach of ESS is discussed and how it can be used related to the concepts of niche construction theory.

Basic tenets

The main purpose of Earth system science is to 'map, monitor and manage the "coupled human and ecological system"' (Lövbrand *et al.* 2009; p. 7). In other words, to try to understand how humans are impacting the Earth at a global ('Earth') scale and to understand the feedback loops between humans and the Earth. In Earth Systems Science, the Earth is seen as a closed system, meaning that only energy can leave and enter the system (Skinner and Murck 2011, Jacobson *et al.* 2000). Solar and cosmic energy enters the system, and energy (via the Albedo effect, for instance) exits the system (Skinner and Murck 2011).

The Earth system is broken down into various subsystems or spheres (see below), which are considered 'open systems', whereby both matter and energy leave and enter the various systems (Skinner and Murck 2011). Open systems are subject to feedback loops, either negative or positive. In negative feedback, the response of the system is in the 'opposite direction from the initial output' (Skinner and Murck 2011; p. 16). In other words, the system will correct itself in the face of change or disturbance, in order to maintain equilibrium. This is considered a stabilising feedback (Skinner and Murck 2011), and can be loosely equated to the NCT notion of counteractive perturbation. In a positive feedback, the effect of the original output is magnified, equilibrium is lost and is unstable (Skinner and Murck 2011). In this case, a new state of equilibrium may be reached; organisms may choose to relocate (counteractive relocation), whilst new colonisers may move in (inceptive and possibly counteractive relocation).

Subsystems or spheres and their interdependence

Unfortunately, there is no real standardisation of the terms used to describe the different spheres. The spheres, generally, are: geosphere, atmosphere, biosphere, and hydrosphere. In climate studies, the heliosphere (sun) is also considered. The cryosphere (frozen water) is considered separate from the hydrosphere by some authors (Butzer 1982, Dincauze 2000). Pedosphere is used by Jacobson *et al.* (2000) for soils. Although not used in this thesis, there could be an argument for this additional subsystem, particularly in the smaller scales, as there are different processes that act on soils than on sediments. The spheres used in this thesis are hydrosphere, atmosphere, geosphere and biosphere.

Another subsystem advocated by some researchers is the 'anthroposphere', which represents 'people and their interests, as well as human impacts on the natural "Earth system"' (Skinner and Murck 2011; pp. 15-16). The different subsystems thus have also been regrouped by some researchers, under two different headings: the ecosphere, which consists of the atmosphere, biosphere, hydrosphere and geosphere (i.e., the 'natural' system) and the anthroposphere (Lövbrand *et al.* 2009, Schellnhuber 1999, Murtugudde 2009).

Although human impact is considered to be much more prevalent in the modern era, and can be seen especially on the global scale, as well as the local and regional scales, the role of human agency on environmental / microclimate change also needs to be considered when looking at the past. Indeed, although ESS scientists (see for instance NASA 1986) do not consider early (i.e., Mid-Holocene) anthropogenic greenhouse production (but see Murtugudde 2009; who points out that humans need to be integrated more fully into ESS), there is increasing evidence of increasing emissions from about 3000BC due to increasing farming and herding practices, especially across the Near East, India and China (Fuller *et al.* 2011, Zhou 2011).

Murtugudde (2009; p. 37) argues that the term anthroposphere 'puts man on that ignoble pedestal from where he appears to be watching the consequences of his actions', thus separating humans from the rest of "nature".' The term anthroposphere will not be used in this thesis as it is unhelpful at best. Humans cannot and should not be separated from 'nature'. Human activities will affect all spheres (locally, regionally and globally) and are part of the various feedback loops. As it is so difficult to separate human induced changes from natural (i.e., climate driven) changes, and because both humans and the environment are modified due to these changes, it would be impossible to define where the anthroposphere ends and the 'ecosphere' begins. Humans are and have been modifying the 'natural' environment for millennia and much of what is seen now and indeed for most if not all of the Holocene is a human made construct: landscapes.

The main aspects, therefore, that are used from ESS include the concepts of spheres (that is: geosphere, biosphere, atmosphere and hydrosphere) and their interactions (feedback loops). Humans are considered part of the biosphere, which conforms more closely with the tenets of CNC theory.

Scales

The perspective of Earth systems science is mainly global. It is concerned with the relationship of the different spheres (however termed) at a macro scale, using data sets particularly from satellites (NASA 1986, Skinner and Murck 2011).

Much of the research is also concerned with modern issues of pollution, land (ab)use, water management, and so on, as well as prediction, for instance, in terms of the sustainability of certain resources, or the output of greenhouse gases (see Skinner and Murck 2011, Jacobson *et al.* 2000). Understanding the interrelationships and feedback mechanisms (or episodes of CNC) between the spheres at a smaller scale, local or regional, is also important, and necessary when trying to understand the mechanisms and causes of past environmental change.

Indeed, some researchers consider that looking at the 'nature-society' relationship needs to be done at different scales (local, regional, global), in order to better understand global change (Turner *et al.* 1990). A major reason for this is that looking at different regional studies gives information on change using different variables, such as population size, socio-economic conditions, political conditions and so on (Turner *et al.* 1990) – information that is lost at a much larger, coarser scale. Furthermore, Murtugudde (2009; p. 38) remarks that 'the Earth system is indeed a system of systems and the regional specificity of the ecosphere and the anthroposphere must be seen as an integrated global Earth system with nested regional Earth systems with their own idiosyncrasies'. This last bit is key: there will be differences across the globe, which will be dependent on different local variables: the niche constructing activities of humans and other organisms, as well as local and regional changes in climate and environment.

Integrating niche construction theory and Earth systems science

Earth systems science posits that the Earth system is made up of subsystems, varying in scale from local to global. These subsystems or spheres, are open systems, so changes in one has implications for the other subsystems in terms of feedback loops. Changes in the atmosphere due to climate forcing will lead to changes in hydrology, which will then affect vegetation and fauna. In this thesis, the biosphere plays the central role, not because of the level of impact on the rest of the subsystems, but because of the nature of the research questions and evidence.

There are two aspects to consider: how external factors, such as climate forcing, may affect biota and how biota may have affected the abiotic subsystems. And this is where niche construction theory plays a crucial and important explanatory role.

If there is a change in the climate, then plants and animals may adapt to these changes counteractively. They may attempt to modify the environment in order to return it to previous or near previous conditions, bearing in mind that many organisms do have manoeuvrability in terms of their preferred ecological tolerances. Thus changes may not occur immediately, because there is no immediate need as certain organisms may still be within ecological tolerance range. Or organisms may choose to relocate. This niche construction activity will, of course, have further implications for the rest of the biosphere and other subsystems.

On the other hand, the niche construction activities of biota will also have knock-on effects on the other subsystems. For instance, lichens (Fungi kingdom) weather (break down) rocks, which in turn are transported or there is soil formation, which can lead to plant growth, which can affect soil structure, hydrology, atmospheric moisture and other evapotranspiration processes (Odling-Smee *et al.* 2003). Vegetation, as seen in the discussion in Chapter 2, has a huge impact on the water budget and cycle. Any changes to vegetation, via human niche construction (humans, of course, greatly modify vegetation), will have repercussions on, for example, the hydrosphere, geosphere and atmosphere (see also Odling-Smee *et al.* 2003).

This understanding of how niche constructing activities of organisms in the biosphere can affect other aspects, such as water budget, soil chemistry and deposition of sediments, helps to interpret the evidence left behind in various proxy records. This, in turn, helps to explain environmental change and the ecological inheritance left for subsequent generations. However, environments are made up of different microenvironments, such as woodlands and wetlands, and can also be broken down in terms of geological, hydrological and biological spheres. NCT also examines parts of the whole – niches – which are on a smaller scale, however, in order to understand environmental change, we need to examine the constituent parts, how they are interrelated and then view the landscape as a whole. This can be done by first identifying the niches to be examined (in this case, arable, woodlands and wetlands), then constructing models of the niches that can illustrate how human modification affect the individual niches and the landscape / environment as a whole.

4.2.4 Models of niche constructing activities in a montaine alluvial environment

General model

The general model for cultural niche construction (CNC) is taken from Odling-Smee *et al.* (2003), but is modified to take into account the relationship between the different spheres of the earth system and human modification (see Figure 4.3). A cultural response, or niche construction activity, will modify the environment as a whole, by modifying one or more aspects of the environment (hydrosphere, biosphere and so on), which in turn modify other aspects. Subsequently, there may or may not be further niche constructing activity in response to the modified environment.

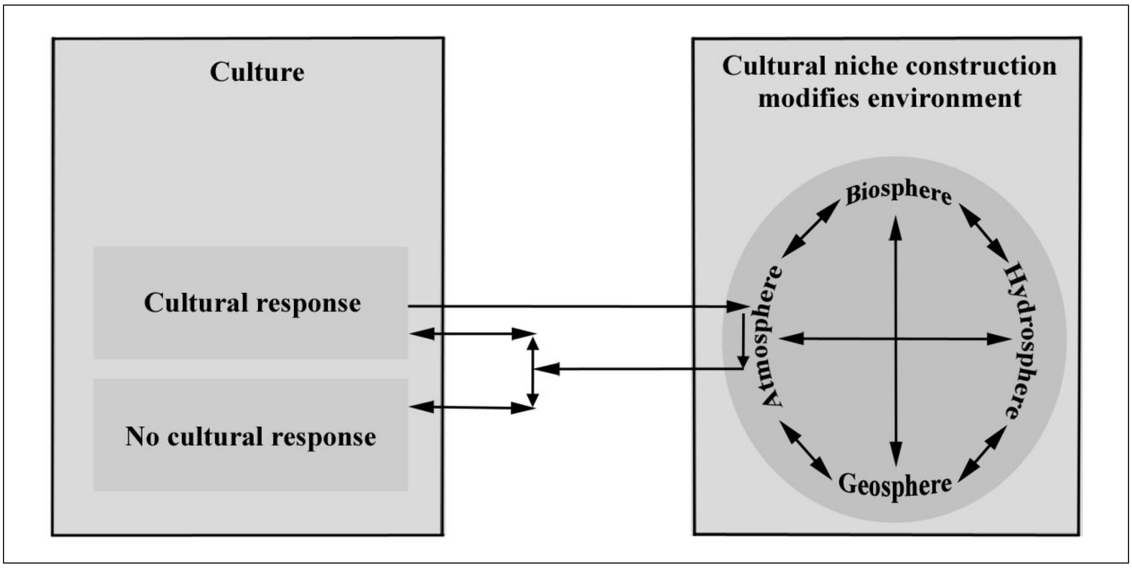

Figure 4.3: General cultural niche construction model: cultural niche construction activities will modify the environment. More specifically, it will modify the different spheres, which will in turn modify each other and thus the environment. This modified environment and strategies employed constitute the ecological and cultural inheritances. Subsequent generations will either respond, which will also modify the environment, or will make no response.

When people settle in a particular area, they 'inherit' an environment. This environment, depending on whether it had been previously inhabited, may or may not be anthropogenically modified. It will have, at least, changed over time due to the interactions of the earth and climate systems. In any case, decisions that are made, in terms of land use and resources management, including farming, grazing, irrigation and procurement of timber, for instance – the cultural niche constructing activities on the existing environment – will modify that environment through the modification of the different spheres, thus leaving a legacy for the next generation. These modifications, the ecological inheritances, may leave traces in the environmental record, in the case of this thesis, in the sediments and phytoliths and other microfossils. The cultural inheritance may be reflected in the environmental evidence as well as the material culture (i.e., texts).

Land use decisions have a direct impact on the sedimentation and hydrology of an area. Climate, too, has an impact. These combined in turn will modify the environment. People are not necessarily directly modifying the environment as a whole, but rather, they are influencing different aspects of that environment (soils, vegetation cover), which in turn leads to that modification of the whole environment.

For instance, to go back to the example of deforestation: when an area in the mountain region is deforested, this will have knock on effects throughout the catchment area of particular river systems. The reduction of trees impacts the evapotranspiration process and thus impacts the atmosphere, which could lead to less moisture in that particular area. The water budget is affected: less water is infiltrated and rather, it runs off above ground. There is also increased erosion and the unstable sediment/soil on the hillsides is washed down into the valley at a higher volume, which has implications for the alluvial plains and arable land. Thus the hydrological system of the river(s) as well as sedimentation patterns are both impacted. In turn this could lead to an increase of high magnitude, less predictable flooding, which could render certain areas unstable in terms of farming unless further action is taken by the inhabitants (further CNC activities). This response, of course, then leads to further modifications of the various spheres, and thus the environment as whole, which could then lead to further CNC activities (or not as is sometimes the case). So, in essence, the modification is on the different spheres, which then leads to the the modification of the environment as a whole, which is then passed down as ecological and cultural inheritances.

As discussed above, different aspects of the environment, hydrosphere, biosphere, lithosphere and atmosphere, are considered separately in the model, but these are not independent of each other. Changes in one leads to changes in the others, so they must be discussed together, to understand how the environment as a whole is modified. However, niches are usually on the smaller scale, and environments are also made up of different niches. These niches are also interdependent – again changes in one will have an impact on other niches (because of the impacts on the different aspects or spheres of the environment). In this thesis, the environment is broken down into three niches: arable, wetlands and woodlands, as these best fit in with the resources and land use strategies that could be employed by different societies. How CNC activities and the model works in different niches, arable land, wetlands management and woodlands management, will now be discussed in more detail.

Arable land use

Arable land use in this case considers all aspects of farming and animal husbandry including grazing and pastoralism if associated with more sedentary societies. Nomadic and semi-nomadic pastoralists are not considered in this model as they fall outside the scope of this study, however, it would also be interesting to model the modification of their behaviours on the environment of their favourite grazing areas.

Arable niche activities include vegetation clearance, manuring, irrigation, burning, cropping/polycropping and grazing (in fallow or post season fields), to name a few. The strategies will impact the different spheres in different ways, which in turn impact each other. So, for instance, burning will impact vegetation patterns as well as the soil itself, hydrology and possibly microclimate. In the case of slash and burn, trees, bushes, shrubs and other vegetation are cut

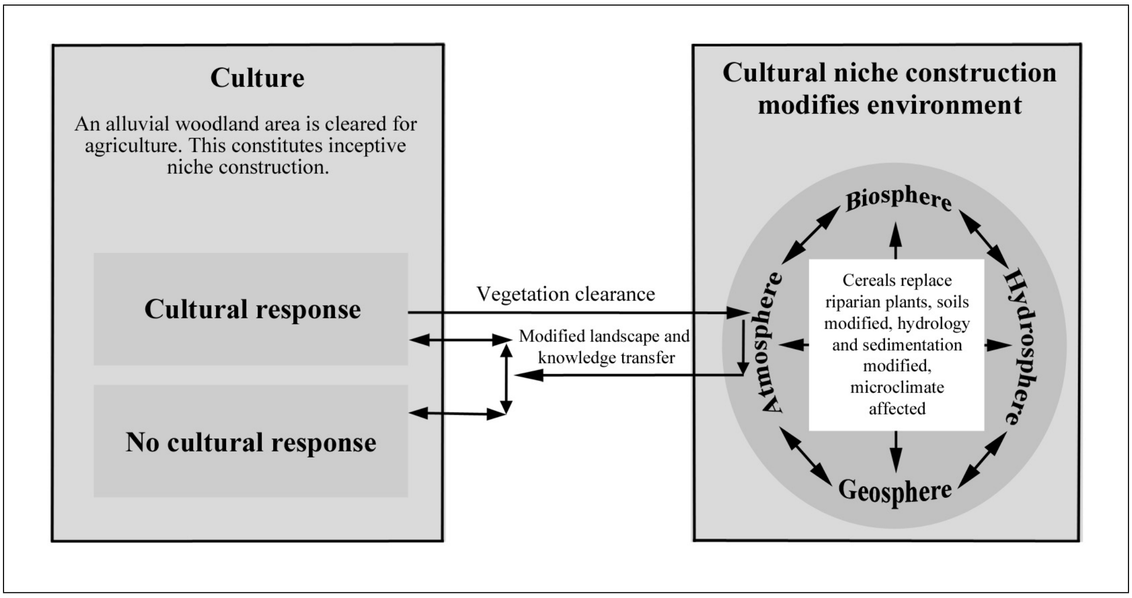

Figure 4.4: The physical environment is modified through farming and associated activities, which can include vegetation clearance, manuring, irrigation, burning, polycropping, leaving fields in fallow, grazing, and others. These strategies will impact the different spheres: soil modification, vegetation patterns, hydrological changes and possible microclimate changes. This knowledge is transmitted via learning through the generations and constitutes the cultural inheritance. The modified environment is the ecological inheritance

and burned to make way for arable fields. This will affect the vegetation, obviously, with woodland (riparian) type vegetation making way for crops and associated weeds. The soil too will be modified: it will be geochemically affected by the burning process, and may be more prone to erosion, both through fluvial and aeolian processes (soils are less stable in open fields). The microclimate may also be affected, as was discussed in the example of deforestation above.

Many of these effects may not be necessarily discernible to the people farming and may have a negligible impact at first. As such, once a riparian environment has been changed to an arable one, for instance, the same strategies may be employed over a period of time.

The landscape that is passed down from generation to generation constitutes the ecological inheritance, the strategies themselves are the cultural inheritance, learned by the younger generations from their elders. Over time, however, the changes the CNC activities have on the environment may became more noticeable, for instance, the soils may lose their fertility. New strategies, such as burning the fields, in situ manuring, and/or polycropping with nitrogen fixers such as legumes may become more prevalent. These in turn will

Figure 4.5: The arable countryside in the Bagum area, Iraqi Kurdistan: some fields are being used, whilst others have been left in fallow. There are few trees to attest to the previous riparian and open woodland that would have existed in the past

modify the different spheres and thus the microenvironment as well (see Figure 4.4 and Figure 4.5).

The offsite microfossil evidence for arable niche constructing activities could include changes in the phytolith assemblages, for instance changing from dicotyledon dominated assemblages to those containing more grasses, particularly cereals and weeds. However, if this area was used for other crops, the changes in the phytolith assemblages may not be so obvious. Legumes, for instance, have few or no silica phytoliths. Irrigation could be indicated through an increase in the jigsaw type phytoliths (see further discussion in Chapters 6 and 7), especially if associated with certain wild/weed plants such as *Setaria* sp.

The individual indicators may not be as robust on their own, and thus the different strands, e.g., different phytolith morphotypes, need to be taken into consideration together, to see if there is an overall picture of change, which could then be attributed to arable activities with varying degrees of certainty. There may also be geochemical markers that could indicate arable activity, via changes made through burning, manuring and different soil formation processes, such as increased phosphate content. Sedimentation patterns are more likely to be a result of niche constructing activities (arable or woodlands management) taking place further upstream.

Onsite evidence will also be important for understanding arable niche constructing activities. Although the phytolith evidence does not give completely accurate environmental evidence, as the plant evidence mainly reflects that intentionally brought to the site, there are still indications of what was grown and used around the site. The onsite data, of course, does not prove in itself what was actually grown in the vicinity (crops may have been imported/traded after all), however, the offsite evidence may corroborate the onsite data.

There are also additional datasets, including artefacts (groundstones, farming tools, etc), macrobotanical remains (usually in the Near Eastern contexts, this consists of charred material) and animal bones and other remains. The presence of sheep for instance, indicates that some herding/grazing may have taken place closer to the site. If there is possible evidence for manuring practices (spherulites or leaf phytoliths in offsite samples for example), it is possible that sheep grazed in the fields post growing season or left in fallow. This manure would have increased the fertility of the soil in those fields, and thus constitutes an arable niche constructing activity. Phytoliths also tend to preserve better in onsite contexts and thus it is easier to identify certain species of grass and cereals with much more certainty, which in turn helps to understand the farming practices of the community.

Wetlands management

Wetlands management niche constructing activities modify the wetlands microenvironments (see Figure 4.6). Although reed and sedge beds may appear to be 'wild', they are resources that were and are used extensively. The mere act of collecting the leaves (and in some cases roots) for use could encourage regrowth. There may also be certain species that were encouraged to grow to the detriment of others. Other wetland plants include species of trees as well. These wetland plants, which grow near or in the channels (natural and artificial), will affect the hydrology and sedimentation of the rivers, slowing the flow of water down for instance (see Figure 4.7. The beds also create environments for certain animal species, including fish, shellfish and birds, which in turn may be hunted/collected by other animal, including human, predators.

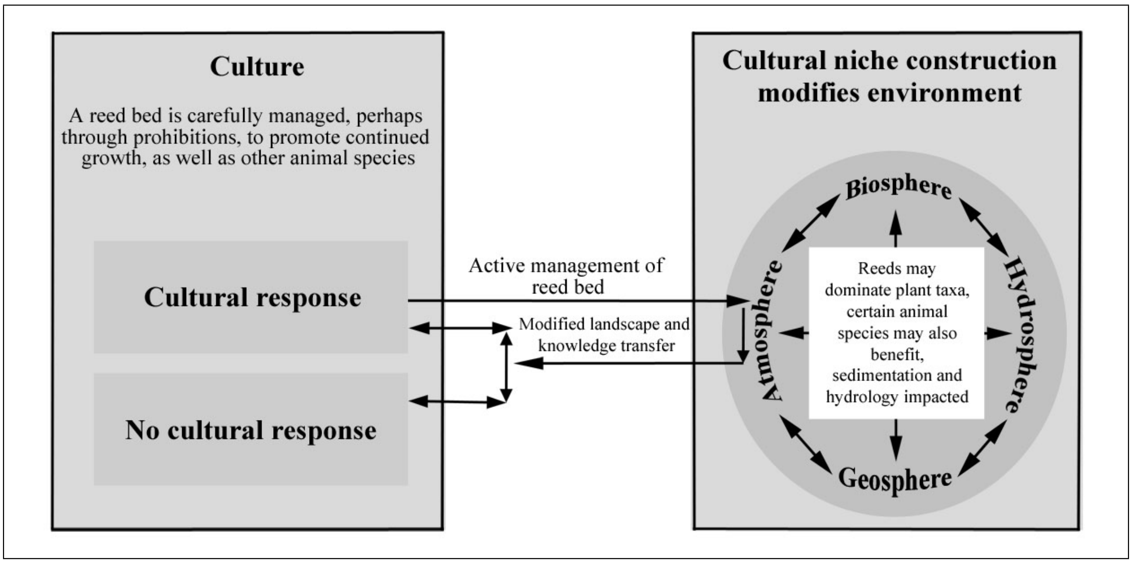

Figure 4.6: The physical environment is modified through management of wetland resources, which include plant resources, muds and fauna. Strategies may include promotion of certain plant species over others, and fish weirs. These strategies will impact the different spheres in terms of vegetation patterns, animal species present, hydrology and possibly microclimate. This knowledge is transmitted via learning through the generations and constitutes the cultural inheritance. The modified environment is the ecological inheritance

Thus the maintenance and cultivation of wetland plants can influence the hydrosphere, lithosphere and biosphere of the microenvironment. The modified landscape constitutes the ecological inheritance, whilst the knowledge of use and maintenance transferred through the generations constitutes the cultural inheritance.

The evidence for wetlands management niche constructing activities will come mainly from onsite contexts, with some confirmation from offsite samples, particularly with respect to the phytolith evidence. Variations in ratios of wetlands plants as compared with other plants such as trees/shrubs and grasses in the offsite samples may indicate some sort of management, but also could indicate fluctuating fluvial patterns (shifting channels). The onsite evidence will give a more substantive picture of wetland resource use. There may also be evidence in terms of bird and fishbones as well as shellfish which could indicate management through preferential collection. Unfortunately, small animal bones, including birds, as well as shellfish have not yet been analysed at either site in this study.

Figure 4.7: A typical alluvial wetlands area, with different species of plants and trees. Note how the sedges and reeds slow down the movement of the river (photo taken at Barnes Wetlands Centre, London, UK)

If a resource is important, then it should be managed properly. If there seems to be a consistent level of wetland plant (and other organisms) use throughout the site's existence, then it is possible that there were some management strategies in place. These could include 'laws' or prohibitions on use. Textual evidence in this regard would be also very useful.

There may be other evidence of the presence of these wetland plants, though not necessarily management of these resources, and this would include sediments (clayey, waterlogged sediments) as well as microfossils such as sponge spicules and certain species of diatoms.

Woodlands management

Woodlands management includes both the modification of the riparian forest / floodplain open woodlands as well as the forested uplands (see Figure 4.8). In the floodplain area, riparian vegetation may be cleared for grazing and arable purposes. This is a dramatic change to the immediate environment and creates a new landscape where grasses tend to dominate. The biosphere is of course modified, in terms of both vegetation and animal communities. The lithosphere and hydrosphere will also be modified. Soils are changed, particularly though the change in organic input (from tree matter to grassland matter) and there is increased risk of wind and water erosion, especially when and where the land is devegetated. Sedimentation patterns are also altered in other ways via hydrological processes.

When the modified floodplain is flooded (either seasonally or flash), there is an increased amount of water and sediment that is run off back into the river system, to be deposited further downstream. Less vegetation (and roots) means that less water is percolated down the profile – this will also have an impact on groundwater levels. The impact of deforestation in the uplands was discussed previously, and again this can have a major impact on the sedimentation and hydrology downstream in the floodplain areas (see Figure 4.9).

Drastic deforestation isn't necessarily always occurring and areas may be managed in a way that will modify the landscape, but not necessarily in a destructive way, at least not in the short to medium term. In many sites, the use of timber for building and charcoal for industrial and domestic purposes is attested. Of course, timber can and was imported, however, usually from the montaine areas such as where these sites are located. As such, it is more likely that the study sites sources their woodlands materials locally rather than imported them from elsewhere.

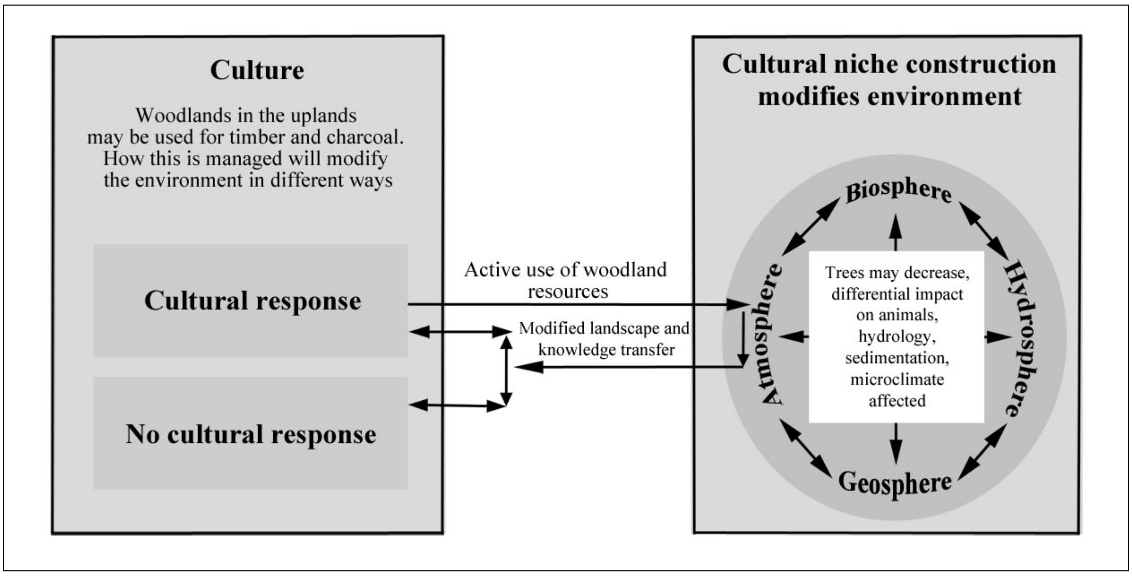

Figure 4.8: The physical environment is modified through management of woodland resources, which include plant resources for timber, charcoal and food, fauna (particularly deer) and other resources such as fungi. Strategies may include promotion of certain plant species over others, and managed (or mismanaged) clearances. These strategies will impact the different spheres in terms of vegetation patterns, animal species present, hydrology, sedimentation and microclimate. This knowledge is transmitted via learning through the generations and constitutes the cultural inheritance. The modified environment is the ecological inheritance.

Both onsite and offsite evidence is important to elucidate woodlands use and management. Like the evidence for wetlands and arable management, the evidence is not conclusive, but it does provide hints. Offsite, phytolith evidence can provide evidence of tree coverage in the vicinity as well as regional forest signals. Again, the condition of the phytoliths in terms of fracturing and other transport indicators can potentially play a role in distinguishing local and regional tree signals and variation. Onsite, the evidence can come from a range of datasets, particularly plants and animals. Both macro- and micro-plant evidence is important.

The use of timber can indicate local resources as can the use of charcoal. Charcoal is very important as charcoal production can be very destructive of woodland resources and management is important in order to ensure a continued supply. Timber and charcoal may, of course, be evidenced in the macrobotanical evidence, but can also be detected in the phytolith evidence (through the identification of dicotyledon wood morphotypes).

Faunal evidence can also be useful, for instance, if certain animals, such as red deer are not only present, but seemingly play an important role in diet and/or ritual practices. Red deer can live in a range of habitats, but the presence of red deer may be indicative of an open woodland in the vicinity. The maintenance of a deer population, especially if central to the site's identity, requires the maintenance of its ideal habitat.

There may also be prohibitions in terms of the use of woodlands resources, textual evidence could be useful if available.

4.2.5 Using cultural niche construction theory to explain cultural change

When discussing the relationship of people and their environments, various key questions repeatedly come up, which generally fall under two basic themes: (i) climate change as a driver for collapse, expansion or other cultural changes of certain societies or regions, and (ii) societal adaptations to these changing environmental conditions. Unfortunately, these questions can limit fruitful dis-

Figure 4.9: The area in the foothills of the Zagros, Iraqi Kurdistan, have been almost completely deforested, although there are some remaining trees at higher elevations. This deforestation will have an impact on the sedimentation and hydrology, particularly in terms of increased erosion, sediment yield and the water budget.

cussion on the human-environment relationship, through presupposition and fallacious argument. The first theme, regarding collapse or expansion presupposes that climate/environmental change is the primary force in the trajectory of societies, even when taking into consideration different socio-politico-economic decisions and variables. There is another presupposition in that certain economic strategies are equated with failure of that society, for instance switching from a predominantly agricultural system to a pastoral one, which is not necessarily the case (Yoffee 2006).

The second theme assumes that people were actually aware of changing climatic/environmental conditions and reacted, or not, to these. People may have been aware of changing conditions, however, there is the underlying premise that people simply react to change rather than also instigate it through their actions. Both types of questions assume that climate/environmental change occurred just prior to the archaeological events, which are therefore reactions to these changing conditions.

However, in attributing environmental change to collapse/expansion, cultural change and adaptive strategies, we fall into the pitfall of falsely attributing one event for causing another, or a *post hoc, ergo propter hoc* fallacy (Damer 2013).

Unfortunately, this approach, one that has societies reacting and perhaps adapting to change does not do justice to what is a very complex relationship. Humans may, in some cases, react and adapt to change (counteractive niche construction), but in other cases, they are the instigators of change (inceptive niche construction). Humans modify the environment, ensuring that it is adapted to their needs, rather than the other way around. Environmental archaeologists have touched upon this, as discussed above, that humans impact the landscape but then revert to the traditional way of thinking in terms of a passive response to change – reaction rather than action.

Using cultural niche construction could be a useful way to address these issues. It is in some ways a bottom-up approach, and in other ways a systems approach. Instead of viewing general climate change as a driver of cultural change (using regional data in a top-bottom approach), it may be more useful to understand how a particular society (or group of societies) managed their landscapes over a period of time – landscape management. We then may be able to see patterns of ecological and/or cultural inheritance and human modification of an environment and possible episodes of further cultural niche construction. We can also see (or at least hypothesise) how these changes impact the biosphere, geosphere, hydrosphere and atmosphere of the particular region.

If dating is constrained enough (and unfortunately this is a big if), then larger cultural changes (expansion, shifts in economic modes) may be discerned, and tied into the modifications of the environment. In most cases, only smaller changes are visible, equally important, such as the introduction of irrigation, increasing deforestation and so on which could be indicators of course, of expansion (more people to feed) and possible mismanagement of resources.

By using cultural niche construction theory and landscape management, in a local to regional scale, a more nuanced understanding is obtainable of why there was cultural change, whether in the form of movement of people, changing economic mode, expansion, contraction and so on.

4.2.6 Concluding comments

Niche construction theory, particularly cultural niche construction theory, enables a better understanding not only cultural change but also environmental change throughout the Holocene. Different questions can be asked of the data, not so much how did climate change impact societies, but rather how did societies manage their landscapes and thus modify their environments, hopefully ensuring their, and their offspring's, survival. This allows researchers to move away from simple discussions of societal collapse due to external triggers and towards a better understanding the nuances of changes in economic modes, agricultural strategies and continuity.

Cultural niche construction elucidates on processes, whilst landscape management provides the details on the actual types of niche construction activities. These activities are provided by the primary phytolith and sedimentary datasets as well as other available datasets.

Together, a new approach can be developed to answer the research questions posited in this PhD, particularly those regarding the human-environment relationship and sustainability.

Chapter 5

Methodology and Methods

5.1 Introduction

Two different methods, geoarchaeology and phytolith analysis, were used in this research project in order to answer the questions posed. Both methods stand well on their own, but are strengthened when combined and more so with the addition of further datasets (macrobotanical and faunal remains and archaeology). Geoarchaeology enables us to understand changing hydrologies and indirectly, changing climate and even provides further information on land use strategies and human modification, such as deforestation. Phytoliths can refine this data by elucidating on crop and resource use, agricultural strategies and changing land use and vegetation, which can also give indirect evidence regarding climate change.

In this section, geoarchaeology methodology and methods are first described. This is followed by a discussion on phytolith methodology and methods, where a criteria for distinguishing land surfaces from alluvial sediments in proposed.

5.2 Geoarchaeology

5.2.1 Methodology

Geoarchaeological methods, based on Earth Science methods (for brief review of history, see Rapp and Hill 1998), in particular sedimentology, include sediment description, analyses for organic content and magnetic susceptibility. These descriptions and analyses give information on depositional mechanisms and environments and hydrological fluctuations and, in turn, can shed light on changes in climate, vegetation, land use patterns, and so on. In other words, impacts from both natural climate variation and human activity, which can be seen in the sedimentary record.

Geoarchaeology addresses these issues on different temporal and spatial scales, simplistically: micro, meso and macro, and different researchers will define these scales in different ways, somewhat arbitrarily. For instance, the micro-scale could include analysis done on a particular site, with further analysis done perhaps in the surrounding region or site catchment (meso scale) and comparing these results to a geographical area, such as southeast Anatolia or the Near East (macro scale). The analysis could be carried out at different time scales, and so could cover anywhere from years / decades to millennia. On the other hand, geoarchaeological analyses may have been carried out only at site level, but even here there are different scales at play: micromorphology, microartefact analysis and sedimentary analysis, carried out in a single room (micro) to the whole site (macro), in a single archaeological period to spanning the entirety of the site's existence (including, perhaps, periods of abandonment).

Geoarchaeology, because of its close relationship with the Earth Sciences, relies heavily on 'uniformitarianism' (Hutton 1795, Lyell 1863). As Gould (1965) points out, there are two aspects of uniformitarianism, substantive and methodological, although often a general 'uniformitarianism' is used to mean both without any distinction, which unfortunately has led to a lot of pointless debate. Methodological uniformitarianism allows the empirical study of past processes, in that models of present processes (for instance, a modern river channel) are applied to observations made to describe and understand past processes that may be evident in a sediment section (Gould 1965).

Substantive uniformitarianism holds that the processes that occur today also occurred in the past, under the same conditions, at the same rate (Gould 1965) and has been modified to include (non-Biblical) tenets of Catastrophism and with the understanding that processes may be different now than in the past, and furthermore that rates may may not be constant (Bailey 1983, Gould 1965, Bell and Walker 2005). In essence, it is important to understand that sedimentary facies from modern depositional systems can only be used as analogues of past systems. However, these are only models that can help to interpret sedimentary facies formed in the distant past, to give possible scenarios of deposition. Modern analogues may not be perfect fits to what occurred in the past (Bell and Walker 2005).

In addition, different variables can lead to similar facies in the sediment record, thus leading to differing interpretations (Boggs 2001). However, this can be somewhat mitigated by using other strands of evidence, including other environmental proxies such as microfossils and stable isotopes. This multidisciplinary approach is advocated by many in the field (see for instance, Butzer 1982, Dincauze 2000, Roberts *et al.* 2001, Wilkinson and Stevens 2003, Bell and Walker 2005, O'Brien *et al.* 2005, Rosen 2007). To this end, phytolith analysis, discussed below, was also carried out on the same offsite samples, and additional samples were taken from onsite contexts, in order to help refine the interpretations. There are also different laboratory-based analyses, in addition to facies description in the field, that can be carried out on the sediments which can elucidate on depositional environments. These include grain size analysis, magnetic susceptibility, loss on ignition, and phosphate analysis, which are discussed in more detail below.

Alluvial environments

Rivers play a key role in the geomorphology of an area through erosion and deposition, and are particularly important in landscape formation throughout the Holocene. They are and have been a key focus of human activity: freshwater resources (water, fish/birds, plants, etc), transport networks, agriculture, settlement and ritual, to name a few (see Figure 5.1). They also have an impact on societies and the remains that they leave behind. Channel switching can have adverse impacts on agriculture and water procurement, for example. Rivers can also bury or erode sites and artefacts. These are some of the reasons why river environments are important to study and understand.

Figure 5.1: Shepherd taking his flock to graze on the banks of the Tanjero river, Iraqi Kurdistan, with ploughed fields in the background

In order to better understand the results of the geoarchaeological field survey and laboratory analysis (and indeed phytolith analysis), a brief exploration of alluvial environments and processes is warranted. More detailed descriptions can be found in Brown (1997), Boggs (2001), Huggett (2007) and Charlton (2008).

Processes

Rivers are born in the uplands. Water from precipitation soaks into the soils and sediments until saturation point, at which point water runs overland, down the slope (Charlton 2008, Waters 1992). This water then incises and concentrates into streams, these small tributaries may then feed into larger collector rivers, forming networks (Strahler system of tributaries: Huggett 2007; see Figure 5.2). Not all precipitation water actually makes it into the streams: much is soaked into the soil, evapotranspired by plants or goes into the water table, replenishing the groundwater (Giller and Malmqvist 2008).

The 'behaviour' of the river is dependent on two controls: slope and discharge. The steeper the slope and the higher the water volume, the higher the stream power of the river (Huggett 2007; length of river and water density also play a role). This in turn affects how much sediment is carried downstream, clast size and erosion. Discharge is influenced by the river's catchment area and precipitation. So the larger the catchment area (i.e., area where the water comes from its streams and overland flow) and/or an increase in precipitation,

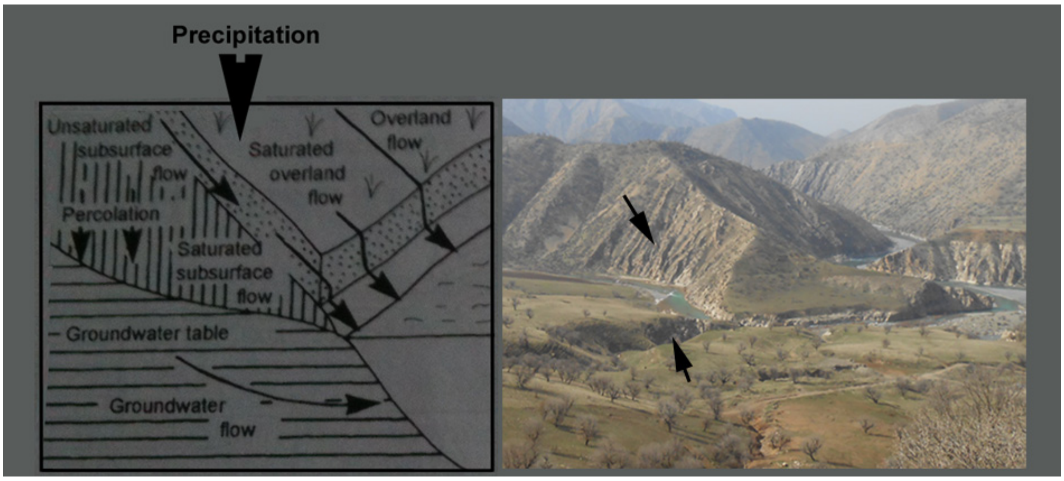

Figure 5.2: On the left is an illustration of precipitation behaviour on slopes; on the right, note the small tributary flowing towards the confluence and incisions on the slopes. Drawing modified from Giller and Malmqvist (2008), p. 4, Fig. 1.2; photo: Maway river confluence, Iraqi Kurdistan

leads to increased discharge (Charlton 2008).

Sediment supply is regulated by vegetation cover on slopes, catchment topography and rainfall. Vegetation on the slopes not only regulates the amount of water which goes into the hydrological system through evapotranspiration (see, for overview, Giller and Malmqvist 2008), but also decreases the erodibility of the slopes and thus the amount of sediment in the channel. If for instance, there is widespread deforestation in the uplands and erratic rainfall patterns due to increasing aridity (a mixture of human modifcation and natural change), then when it does rain, there will be a very sudden increase in discharge and sediment supply, which then results in poorly sorted flood layers in the terrace sections.

The term 'stream' refers to any flowing water and includes rills, gullies, wadis and channels (rivers). Streams can be perennial, intermittent (only wet season) or ephemeral (only when there is rain or snow melt) (Waters 1992). There are also different types of rivers: straight, meandering, braided and anastamosing, although many rivers have characteristics of more than one type.

A river meandering through the plain displays varying degrees of sinuosity (curvature), which can become more extreme as erosional processes occur. As the water flows, it goes faster on the outside of the bend and erodes sediment from that side of the bank (lateral erosion). The river carries that sediment to the opposite bank, slightly downstream, where the velocity decreases and the sediment (usually gravels) is deposited, known as lateral accretion (Huggett 2007, Charlton 2008, Boggs 2001). This process is known as helical flow (Boggs 2001).

As this process of erosion and deposition occurs, it causes the river to move laterally across the plain, unless impeded by topography. A river can also change its channel via avulsion. Avulsion or channel jumping, is rapid and can be caused by flooding, that is, spring melt or deforestation flooding (Charlton 2008, Waters 1992), or through tectonics (if there is subsidence in the basin and part of the land surface moves downwards, the river will follow). Oxbow lakes are created when a river becomes so sinuous that two parts of the channel meet and that part is cut off. The oxbow lakes and abandoned channels eventually fill up with silt and organic material.

The flow of meandering rivers tends to be even, however, may be punctuated by annual flooding, with increased discharge and alluviation on the floodplain. Some rivers flood more often than others.

Floodplains are formed by sediments being deposited when the river channel floods. This is called aggradation, overbank deposition or alluviation, as sediments are deposited on top of each other in layers or strata. There are different components of a floodplain, including levees, backswamps, distal and proximal areas (see Figure 5.3). The sediments found in these microenvironments are discussed below.

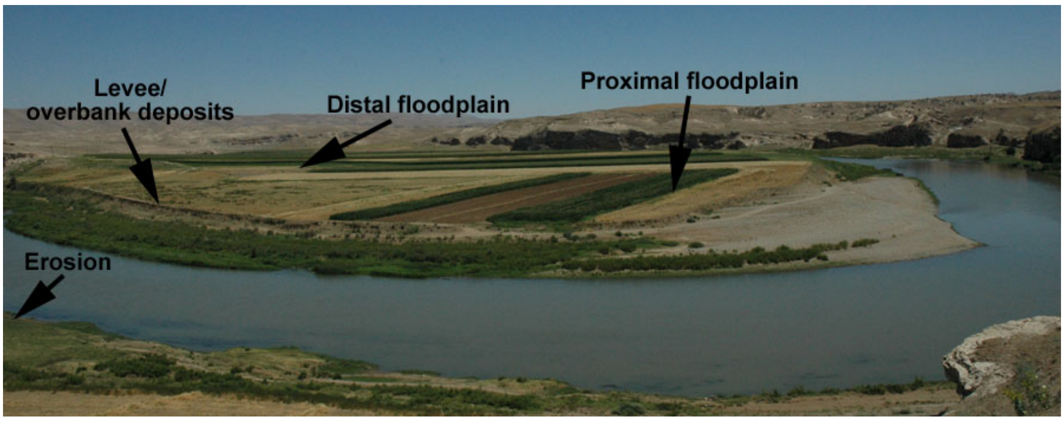

Figure 5.3: The main components of what was an active floodplain earlier during the Holocene. Hirbemerdon Tepe, SE Turkey

There are two types of river terraces, bedrock and alluvial terraces. It is the latter type that will be discussed here. Terraces are formed through cycles of alluviation and incision. When a river alluviates, it creates the initial floodplain; the river then begins to incise (vertical erosion), cutting into the former floodplain, creating a new channel and terrace. When the river begins to alluviate again, it creates a new floodplain, at a lower level. The higher terraces are usually the oldest and the lower ones should, therefore, be younger (see Figure 3.8). However, in some cases, because of channel switching for instance, some terraces become buried under younger sediments (see Huggett 2007, Charlton 2008).

Sediments

Coarser sediments are indicative of higher energy (increased velocity) and finer sediments of lower energy.

The idealised model of a river section is an erosive base of conglomerate lag, the sequence then fines up with sands (cross stratified often) then silts depending on flow type and energy (for more detail, see Huggett 2007), clays and finally perhaps pedogenesis (soil formation). This is also a model best applied to aggrading rivers than those are laterally accreting. Unfortunately, different rivers behave in different ways in different parts of the river system so not all rivers sections will follow this model exactly.

Different parts of the river and associated plain will have somewhat characteristic sediment types. Channel lag (or cut) deposits consist of lag and channel deposits (Boggs 2001), i.e., gravels possibly, with sands and silts. Channel bar deposits (bars, point bars), where there is lateral accretion, may contain cross stratified sands as well as gravels or muds in a fining up sequence (Boggs 2001), depending on river velocity. Overbank deposits (floodplain deposits) are normally fine grained (Boggs 2001) and fine out laterally, so that coarser grains (sands) are more proximal to the river (and make up levee deposits) and finer grained silts and clays are deposited in the more distal backswampy areas of the plain (Boggs 2001; see Figure 5.3).

Soil formation

It is often assumed that in order for soil formation (i.e., pedogenesis) to occur, there has to be a lengthy period of stability and vegetation, where there is no deposition or erosion of sediments (Kraus and Bown 1986), and in fact palaeosols found within stratigraphic units are used as evidence of past stability. Lengthy stability is certainly necessary for pedogenesis to occur on weathering rock itself (Kraus and Bown 1986). The development of horizons (A, B, C) would also take a longer period of time. However, incipient soil formation on deposited unconsolidated sediments does not require long periods of stability.

Although alluvial environments are often viewed as being dynamic due to shifting river channels and flooding, it may be better to view them as stable, with 'episodic' sedimentation and erosion (Kraus and Bown 1986; p. 182). Soil development can and does occur in alluvial settings (and the soils are very rich in nutrients), however, it can vary from fully developed soils with associated horizons which take centuries to develop to young incipient soils with very weak A horizons. This will dependent on how active the environment is ('net aggradational versus net degradational': Kraus and Bown 1986; p. 186). Some of the palaeosols may not even be recognisable in section, and indeed it is possible to have soil surfaces in what appear to be sedimentary units: alternating sand and clay units may either be reflecting deposition (from river alluviation) or clay translocating down the soil profile (a soil formation process) (Retallack 2001).

Geoarchaeological lab analysis

Sediment description

A visual description of sediments in section is very helpful in establishing modes and energy of transport, as well as any (visible) diagenetic/post depositional or soil formation processes that may have taken place after deposition. For instance, grain size changes can indicate changes in the energy level of transport, colour could indicate oxidising or reducing conditions (i.e., drying / wetting).

Individual samples were also described in the field lab using the following parameters: colour when wet and dry (using the Munsell colour chart), grain size, sorting, roundness, sphericity, and consistence (plasticity and stickiness, clay content). Any other interesting features, such as inclusions, were noted as well. These were recorded on forms, especially designed for this thesis and which can be found in Appendix A. A hand lens (x10) was also used in some cases to help identify the inclusions.

Colour can give information on source material, weathering, organic content, post depositional changes and geochemistry of the sediments (Rapp and Hill 1998). Munsell soil colour charts were used, which allows for some standardisation – although determining colour can depend on light conditions and whether or not the sediment is dry (Rapp and Hill 1998), and can still be subjective, depending on the user. The colours were usually assessed outside in the morning sunlight although sometimes in the shade, as the sun moved. However, the samples were also described in the same laboratory light conditions and were described for wet and dry conditions.

Grain size, sorting, roundness and sphericity can indicate transport energy and distance. Larger clasts, such as gravels, need higher velocities to be transported and are transported as bedload along the channel bottom. Sands are also usually bedload but need less velocity. Silts and clays tend to be transported as suspended loads and can be carried for greater distances. Roundness of grains also indicates a longer transport distance. Poorly sorted material tends to point to short transport distances and/or flooding (high magnitude) events. Consistence gives information on the content of the sediment, for instance, clay content, which in turn can also indicate transport energy.

Grain size analysis

Grain (or particle) size analysis is used to help determine energy of transport, and thus depositional environments (backswamp versus channel, for instance). This in turn may elucidate on, for example, changing hydrologies of a river system due to fluctuations in rainfall, deforestation and other environmental and climatic effects, as discussed above.

Magnetic susceptibility

Magnetic susceptibility measures the degree of magnetism of the soil/sediment, which could indicate sediments associated with burning and/or soil weathering processes (Clark 1996).

The dual frequency readings were taken to distinguish between bedrock-weathered material (low frequency readings) and human-modified sediment – some of these effects include burning and cultivation, which precipitate 'ultra-fine secondary iron oxides' detectable through the high frequency readings (Clark 1996; p. 102-3). Additional dual readings of the samples were taken after loss on ignition (i.e., after the organics were burnt off, see below) in order to measure the maximum potential for magnetic susceptibility and possible iron content of the sample. This was done because organic matter can mask true levels of magnetism in sediments (Gale and Hoare 1991).

Loss on ignition:

Loss on ignition (LOI) measures the organic composition of sediment. There are some drawbacks to this method, particularly in relation to the high furnace temperature. Gale and Hoare (1991) point out that at these temperatures, some minerals could dehydrate, leading to weight differences (between pre- and post-firing) being higher than they should be. However, Gale and Hoare still recommend a methodology similar to the one used here (including similar temperatures: 500°C versus 550°C). Experiments by Heiri *et al.* (2001), indicate that there are variations in LOI readings dependent on temperatures, furnace time, position of sample of in the furnace and sample amount. These variations differed across different laboratories, and the main conclusion was that when using LOI in a study, one should include all of the parameters in the methods discussion (and presumably, to use the same method all throughout the LOI procedure on all samples). In essence, LOI concerns looking at the relative differences between samples to see if any stand out in terms of organic content, and as long as the same procedure is adhered to throughout the analyses, any patterns should be considered valid. In the end, only rough estimates of organic content are needed, which can be relatively compared with the other samples.

Spot phosphate (the Gundlach method):

Spot phosphate analysis (Gundlach method) was conducted to measure the relative phosphate content of the samples, and so determine areas of high concentrations, where there may have been human occupation. It is not possible to distinguish between inorganic and organic phosphates with this method, and thus higher readings should be used cautiously, as they do not conclusively indicate areas of human occupation, animal penning or soil formation.

5.2.2 Methods

Geoarchaeological analyses were carried out on offsite samples from Hirbemerdon Tepe and Bakr Awa. In both cases, an offsite trench was excavated in the Holocene terrace, and the sections of these were drawn, photographed and sampled. Further sections (from terrace, wadi cuts, quarry cuts and similar) were cleaned, recorded and sampled as well. The samples were taken, with relevant permissions, from the sites to the Sediment Laboratory at the Institute of Archaeology, University of London, for further analysis.

The Hirbemerdon Tepe samples, taken in 2008, were described, and were analysed for grain size, phosphate and organic content and magnetic susceptibility. The Bakr Awa samples, which were collected in the late summer of 2011, were described in the field (in section) and in the laboratory (bulk samples), but due to time constraints of this PhD, no further analysis has yet been carried out. Further cores have been taken nearby and additional trenches have been excavated in the Shahrizor, and these sediments, along with the original trench sediments will be analysed in late 2014.

Sampling strategy

Because of the nature of the research questions, geoarchaeological analysis was only done on the offsite samples. Onsite analysis would have enabled answering questions regarding site formation processes for instance, and while important, do not fall under the purview of this thesis. At Hirbemerdon Tepe, through field survey and desk-based research (especially the descriptions from

Doğan 2005a), it was possible to locate the Holocene terrace (Doğan's T4). A trench, measuring 4m deep, 1m wide and 1m long, and dubbed 'Wadi Shaitan' because of the heat and plethora of insect life at the bottom was dug by hand. It was located near the environs of the tell itself and the lower town, next to the Tigris river. The sedimentary record of this trench stretches from at least the Early Holocene into the Mid-Late Holocene (see Chapters 6 and 7).

Upstream, to the northeast of this trench, were the eroded sections of the edge of the same terrace. Although many of the sections were severely weathered thus rendering recording next to impossible, a few sections which could be cleaned to some extent and in which sedimentary units could be discerned were located. Cleaning most of the sections would have been impossible: the constant wet-dry effect had made the sediment very crumbly and in many cases, this effect went through the sediments to quite a lateral 'depth'. They were also very high, measuring up to about 8m. My assistant, Ismail Uzum, and I tried to clean several sections with a pick axe and trowels, without success. The sediment crumbled, the overhangs became unstable and still no stratigraphy could be discerned. However, as mentioned, we did find a couple of sections which were not so badly weathered, and where stratigraphy could be seen and which benefited from some cleaning. It was these sections that were recorded and sampled.

In Iraqi Kurdistan, the survey area was in the Shahrizor plain, in the province of Suleimaniyah. There is a major river, the Tanjero, which runs north to south along the plain and joins the Sirwan (upper Diyala) in an area now inundated under the Darband-i Khan dam, as well as some smaller tributaries and wadis.

Figure 5.4: The two trenches in comparison: the Hirbemerdon Tepe trench (1 x 1 x 4m) is on the left, The Bakr Awa trench (22 x 4 x 6m) on the right

Sections from channel, water well and quarry cuts were examined and recorded from across the plain, stretching from the city of Suleimaniyah in the north towards Halabja in the south. A very large trench, measuring approximately 40m x 20m x 7m was also excavated in the floodplain between two sites (Bakr Awa and Gurga Chiya), and further trenches were excavated in the Bagum and Yasin Tepe areas. The first trench was so large as a backhoe was not available, so an excavator was used instead. It was a huge contrast to the much smaller Hirbemerdon Tepe trench (see Figure 5.4). Cores were also taken in the Bakr Awa area. The first, big trench, will be the focus of this thesis, with reference to the other trenches and cores. This plain is crisscrossed by many wadi channels of varying dates (channel cuts were also discerned in section). Samples were taken for geoarchaeological and microfossil (phytolith) analysis from the trench as well as the cuts.

Samples were recorded on the 'sample log' form (Appendix A) for each site, and given numbers which were used in the laboratory as well. Samples taken were also indicated on the stratigraphical forms discussed below.

Sediment description

Recording forms were designed especially for this project, based on standard grain size sedimentary logs used in Earth Science sediment/stratigraphy studies (Appendix A). The form includes a grain size/lithology column and has an area to record, laterally as well as vertically, an area of the section. This enables one to look at changes across the section including lenses, smaller areas of mottling and channel cuts (i.e., gravel beds). These forms, which are used to record changes in colour, sediment features, grain size and inclusions (roots, shells, etc) in a standardised manner, should make recording and interpretation easier. Drawings were done in the field on these forms, then scanned in and processed in Photoshop Elements. Samples (sediment, phytoliths and others) taken were also indicated on these drawings. The stratigraphy was also recorded in written form when samples were taken (see Appendix A). This form was used to describe physical attributes of samples as well as a cross reference to any other records (photographs, drawings, subsamples, etc).

Each geological section was photographed and drawn, and sediments samples were taken (indicated on the forms) for further analysis. (Other samples were also taken, including charcoal, pottery, and seeds.)

Individual samples were then further described in the field lab using the following parameters: colour when wet and dry (using the Munsell soil colour charts), grain size, sorting, roundness, sphericity, and consistence (plasticity and stickiness). Any other interesting features, such as inclusions, were noted as well. A hand lens (x10) was also used in some cases to help identify the inclusions.

Grain size analysis

The method used was the traditional, manual hydrometer and wet sieving techniques (Krumbein and Sloss 1951). Approximately 20-35 g per sample was used for this analysis. The samples were first wet sieved through a 0.625 mesh to separate the sand fractions from the muds (silts and clays). The fine grained sediment (<0.625mm) was placed in a 1 litre settling cylinder, which was filled with 40ml of sodium hexametaphosphate (calgon: a deflocculant, which separates clay particles held together by ionic bonds) and distilled water, bringing it to a total volume of one litre. The mixture was then manually 'agitated', using up and down motions with a stirring rod, to ensure that all of the sediment was in suspension. Hydrometer readings, based on Stokes Law of Settling calculations (Boggs 2001; see Appendix B) were taken at specific intervals to measure the density of individual particle phi sizes. Control temperature and hydrometer readings (in distilled water) were also taken. The control hydrometer readings (corrective factors) were subtracted from the sample hydrometer readings to obtain corrected readings. Stokes Law calculations are based on sediments in pure water, however, calgon makes the water heavier, affecting its viscosity and hydrometer readings; temperature too can affect readings and so control readings are necessary. Cumulative coarser percentages (the percentage of sediments that have settled versus those still in suspension) were calculated using the formula: (total sample weight - corrected reading) / total sample weight.

The remaining coarser-grained sediments were placed in beakers and oven-dried at 50°C and dry-sieved through nested sieves corresponding to the Udden-Wentworth scale. Each fraction was weighed and the cumulative percent coarser calculated. Once the cumulative percent coarser figures were calculated, they were plotted in two types of graphs: a curve and histogram. The curve graph measures the 'cumulative percentage frequency against size (phi class)'; the histogram gives information on modality and skewness (Gale and Hoare 1991; pp. 60-1). The grain size curve graph was plotted by hand, using log-10 graphing paper.

Calculations for mean, standard deviation, skewness and kurtosis (Folk and Ward 1957, Gale and Hoare 1991) were also carried out on these samples, in order to obtain further detail on the depositional mechanisms (formulae can be found in Appendix B). Mean gives the average grain size, skewness indicates if the grain size tends to be more coarse (positive) or fine (negative). Alluvial sediments, such as these, tend to be more positively skewed (Rapp and Hill 1998). Standard deviation gives further information on the sorting of the grains. The higher the deviation, the more poorly sorted the sediment is (Gale and Hoare 1991). Kurtosis describes the peak of the graph, from platykurtosis to leptokurtosis (high peak). A high peak indicates good sorting, a flat curve (platykurtic) indicates poor sorting. These statistical analyses can confirm or deny the physical description of sediments and more accurately define transport energy.

Magnetic susceptibility

For this analysis (for methodology, see Gale and Hoare 1991), about 10g of each sample, sieved at 2mm, was placed in diamagnetic containers and measured for magnetic susceptibility levels using a Barrington MS2 meter and Sensor Type MS2B. Low and high readings were taken.

This method can be useful in helping to detect possible land surfaces (i.e., palaeosols), which may not be seen in section.

Loss on ignition (organics)

The samples used for the magnetic susceptibility analysis were used in this analysis, and the protocol followed was the one used by both the Geography department and the Institute of Archaeology (UCL). First, the 10g samples were placed in ceramic crucibles, weighed and fired in a furnace at 550°C for two hours. After firing, they were weighed again. Loss on ignition percentage is calculated using the equation: (initial weight) - (post-firing weight) / initial weight.

The carbonate composition of the sediment samples was not measured for this study.

Phosphate analysis: the Gundlach method (Gundlach 1961)

About 50 mg, sieved at 0.5 mm was used. Each sample was placed on ash-free filter paper, then two drops of ammonium molybdate was added to the sample. After 30 seconds, two drops of ascorbic acid were added. After two minutes, blue colouring appeared on the paper, which was categorised (0-3 scale) by eye. The scale represents the concentration of phosphate in the sample 0 being the lowest and 3 being the highest concentration.

5.3 Phytoliths

5.3.1 Methodology

Background

Microfossil analysis involves the microscopic analysis of floral and faunal microfossils present in sediment samples. Particular types of microfossils (such as phytoliths (see Figure 5.5), diatoms and ostracods) are identified and counted, the idea being that changes in species communities reflect (indirectly) changes in climate and the environment. These changes can be influenced by anthropogenic and non-anthropogenic factors, and furthermore this evidence can be used to further substantiate interpretations and add details to the picture.

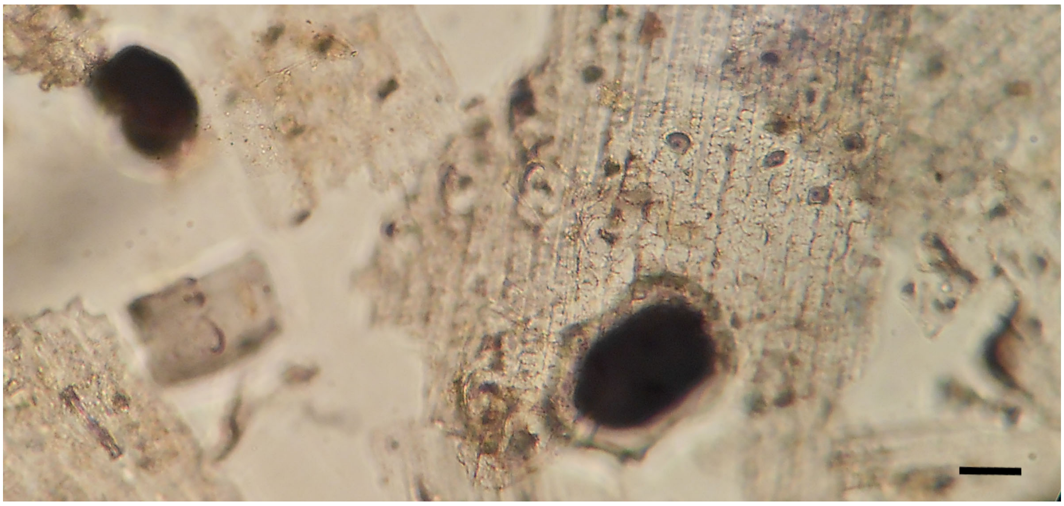

Figure 5.5: Wheat husk multicells from Bakr Awa. Bar is 10 micrometres.

Instead of simply looking at changes in sediments, the biostratigraphy, which reflects changes within communities of plants and animals (for more information, see McGowran 2005), can also be analysed. There are, of course, many other aims of microfossil analyses (including dating of layers, sea level studies, evolution studies and so on: see Armstrong and Brasier 2005, McGowran 2005).

Phytolith analysis is a useful method, especially when applied to questions of changing agricultural practices, crop and resource use, and climate, environmental and vegetation changes. There is a variety of phytolith types, which are essentially minerals that plants produce, including opal silica, calcium oxalates, aragonite, calcite and vaterite to name a few (Weiner 2010). Plants (primarily grasses, sedges and palms) naturally take up soluble silica from soil water and this silica then fills intra- and extracellular spaces in the plants (Piperno 2005). These are opal phytoliths (plant rocks). Because silica is durable, it preserves well in most archaeological and environmental contexts. Silica (or opal) phytoliths are most commonly used in archaeological and environmental studies (Weiner 2010), with some research as well into calcium oxalates (e.g., Cummings 1992). The phytoliths used in the dissertation are opal phytoliths and will be termed as 'phytoliths' in this thesis.

Development of phytolith research and research approaches

The history of phytolith research is discussed in more detail elsewhere (see for instance, Piperno 2005, Twiss 2001, Stromberg 2004, Rovner 1971) so will only be discussed briefly here.

Although Ehrenberg identified and drew examples of phytoliths, diatoms and pollen in his book published in 1847, using samples obtained from Charles Darwin in the 1830s while on the Beagle (Twiss 2001, Ehrenberg 1847), it was not until the 1970s that phytolith analysis really came into its own in archaeology and palaeoecology (Stromberg 2004).

In spite of the active research and discussion into phytoliths, including taphonomy (Madella and Lancelotti 2012, Cabanes *et al.* 2011), methodology (Rosen 2005, Sudbury 2010, Shillito 2011), formation of phytoliths and silica pathways (Piperno 2005, Raven 1983), identification and nomenclature (Kealhofer *et al.* 1998, Madella *et al.* 2005), and applications of phytolith research including palaeoecology / palaeoenvironments (Alexandre *et al.* 1997, Runge 1999, Fredlund and Tieszen 1994), climate (Webb and Longstaffe 2002; 2003), onsite crop and resource use (Harvey and Fuller 2005, Rosen *et al.* 2000, Rosen 2005, Ryan 2009; 2011, Albert and Portillo 2005) and irrigation (Jenkins *et al.* 2011, Rosen and Weiner 1994, Madella *et al.* 2009) to name a few, there is little standardisation and much work still needs to be done.

For instance, in terms of standardisation, there are three issues: nomenclature, processing, and data collection and analysis. The problem with standardisation of nomenclature has been addressed by Madella *et al.* (2005). Although perhaps somewhat biased towards morphometric and 3-D analysis of phytoliths, it is comprehensive and recognises that certain terms have become so entrenched in phytolith literature (termed *nomina conservanda* by the authors), such as rondel (see Figure 5.6), that they do not need further descriptors (Madella *et al.* 2005). Most practitioners, including myself, do tend to follow this nomenclature, but with a caveat of 'wherever possible'. Part of this is because new forms are seen, but it is not possible to determine if they are diagnostic, and so are listed with new descriptors which may or may not conform to the nomenclature. It is also a work in progress, and some may disagree with some of the terms, or keep to their preferred nomenclature, which can lead to multiple names for the same morphotypes.

The processing of samples is also not standardised. There are many different methods, which involve different chemicals, furnace times, order of processing (see, for instance, Rosen 2005, Albert and Portillo 2005, Sudbury 2010). Even the mountant used may vary – usually either Canada Balsam or Merck New Entellen. Some of the differences are due to how the samples are analysed – for instance, Canada Balsam enables the researcher to rotate the phytoliths to see them in three dimensions. The different laboratory procedures and their possible effects on phytoliths is discussed further below.

Finally there is little standardisation in how analysis is performed and how the data is 'crunched' (see for a lengthy discussion, Stromberg 2004). For instance, some researchers prefer thin sections (Shillito 2011), while others prefer working on extracted phytoliths on slides (Rosen 2005). Some researchers work on morphometrics of single cells, studying shape and size and characteristics to more precisely identify a morphotype (Stromberg 2004), while others identify morphotypes using 2-D descriptors (Rosen 2005, Albert and Portillo 2005) as well as multicells.

There is also a difference in how phytoliths are quantified and represented in graphs. Some use percentages (Albert and Portillo 2005) while others work in abundance/absolute counts (Rosen 2005), although often both are used in papers, to look at temporal and/or spatial trends across samples.

And finally some researchers concentrate on indices based on the ratios or percentages of certain morphotypes compared to other morphotypes. These indices (Iph for aridity, Ic for climate, Fs for water stress and D:P for tree cover) are discussed more fully below. In the case of the various indices, there is another lack of standardisation, concerning which morphotypes are included in calculating the ratios (see below). Whilst these may seem like small variations, and in some cases may not effect the results too much, in other cases there may be a certain level of data skewing, in that different morphotypes included could give different results for the same sample.

The fact that phytoliths can be used in so many different ways should not, however, be seen in a negative light. For instance, thin sections and slides with extracted phytoliths, or Excel charts versus indices, can be used to answer different research questions. However, combining the different results may yield different pieces of information thus giving a more complete picture of trends, vegetation change and so on. To this end, the phytolith data in this thesis has been 'crunched' in a number of ways: absolute numbers, percentages, correlation, and a variety of indices.

Phytolith formation

Opal phytolith formation in plants is a complex process and not completely understood (Piperno 2005). After oxygen, silica is the most abundant element found in soils (Epstein 1994). Soluble silica or silicic acid ($Si(OH)_4$) is derived from the weathering of rocks and dissolved 'biologically deposited' SiO_2 (the solid form of silica) (Raven 1983; p. 179). This silica in solution is taken up by plant roots and transported through the xylem and remains in solution until finally becoming polymerised and deposited as the variously named amorphous, biogenic, hydrated or opal silica (SiO_2*nH_2O) (Epstein 1994). The silica is deposited within and without cellular areas in the plant, including in the leaves, stems, inflorescence, seeds, xylem, etc (Piperno 2005).

While the plant is living, the silica plays a role in strengthening plant cells, enabling plants to stand erect and leaves to be well positioned for sunlight (Epstein 1994). The silica may also help plants to resist fungi, parasitic plants and herbivores (Epstein 1994). This process is still not well understood, particularly in reference to why plants make phytoliths in the first place, although there seems to be evidence that phytoliths are produced to limit herbivore, including insects, activity (Piperno *et al.* 2002).

Once the amorphous silica is deposited in the cells and extracellular spaces, it takes the shape of these areas, and it is the morphological attributes that are studied, identified and quantified (as discussed above). So for instance, in a leaf or stem, long and short cells, stomata, mesophyll, hairs, tricomes, bulliforms, etc (see Figure 5.6), can all be infilled with amorphous silica, and potentially be

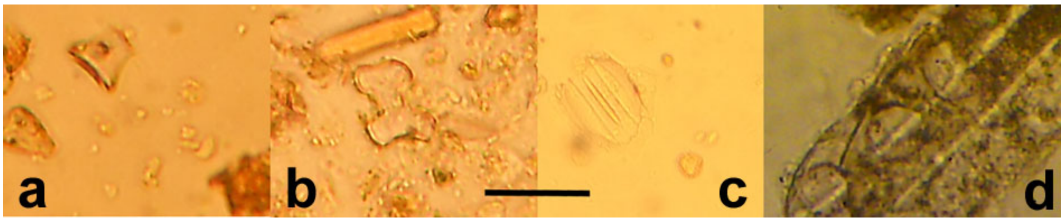

Figure 5.6: Some examples of phytoliths: (a) rondel; (b) bilobe; (c) stomata; (d) sedge with visible mesophyll. Bar is 10 micrometers.

preserved in soils and sediments. The process of silicification in cells and other plant parts may not be complete, for example, short cells such as bilobes may not be completely infilled by silica. After deposition, this partly silicified phytolith may be difficult to identify. These partly silicified cells may also account for the 'weathered' (i.e., ones that look fractured and dissolved) phytoliths that Cabanes *et al.* (2011) found in modern ashed samples (see also, Madella and Lancelotti 2012), and by extension some 'weathered' or dissolved phytoliths found in fossil assemblages.

Once the plant dies and decays, the phytoliths are released into the soil (O horizon), at which point complex taphonomical processes take over, which are discussed in more detail below.

Not all plants produce phytoliths, and ones that do so, produce them in varying numbers. Raven (1983; p. 188) estimates that 'SiO_2 content as a fraction of the dry weight' for wetland plants is 10-15 per cent, dryland grasses is 1-3 per cent and dicotyledons is less than 1 per cent. However, soil $Si(OH_4)$ will vary according to soil type and water availability may also play a role (Raven 1983; p. 188). In addition, it should be noted that there are various forms of phytoliths, including opal (silica-based) and calcium oxalate phytoliths. Due to methodological constraints (see below), it is only the opal phytoliths that are studied and discussed in this thesis, however it is hoped that future analysis will also include calcium oxalates as well.

Piperno (2005) has comprehensive lists of plants that do and do not produce opal phytoliths, however, subsequent experiments with modern plants have provided amendments to these lists (see for example, Madella and Zurro 2007; and articles therein). Although it is not clearly understood why some plants produce opal phytoliths and others do not (Piperno 2005), and for that matter, why the numbers and types of phytoliths can also vary, one reason may be physiological. Some plants, such as legumes, may have some sort of 'barrier' located at the root, which prevents the uptake of $Si(OH)_4$, thus these types of plants will produce very few, if any, opal phytoliths (Raven 1983).

The rate of evapotranspiration is related to phytolith formation. Evapotranspiration is defined as the 'amount of water evaporating from soil and transpired through plants' (Cristea *et al.* 2012; p. 1). The rate of evapotranspiration is dependent on a number of variables including: air temperature, relative humidity, wind speed (at 2 metres) and solar radiation (Cristea *et al.* 2012; see Figure 5.7). In the Near East, where there is a high rate of evapotranspiration, there is a higher deposition of silica, so more phytoliths are produced (Rosen 1992, Piperno 2005). In addition, because of these very conditions, more multicells are produced (Piperno 2005), which is very useful in terms of genus identification.

Different factors come into play in different climate regimes. For instance, it has been found that solar radiation is key to evapotranspiration rates in humid and sub-humid climates, whereas wind speed is very important in more arid regimes (Cristea *et al.* 2012). In the Near East, the climate regime, of course, changes through the Holocene, becoming generally more arid. Solar radiation would have played a prominent role throughout, with perhaps increasing importance of wind speed (at 2 metres). Water availability is also very important – there has to be water in order for there to be evapotranspiration, and by extension, phytolith production. This water can come from a variety of sources: rivers, rainfall, groundwater and of course, through human agency – irrigation. If there is increased evapotranspiration, there is higher silica saturation (due to water evaporating) and more water is drawn up through the plants for transpiration, and thus more soluble silica or silicic acid ($Si(OH)_4$) is deposited in plant cells.

However, this being said, there is increasing evidence of many different plants (monocotyledons and dicotyledons) producing phytoliths, regardless of climatic conditions (Piperno *et al.* 2002); they are also produced in parts of plants where there is no evapotranspiration, such as stems (Weiner 2010). While

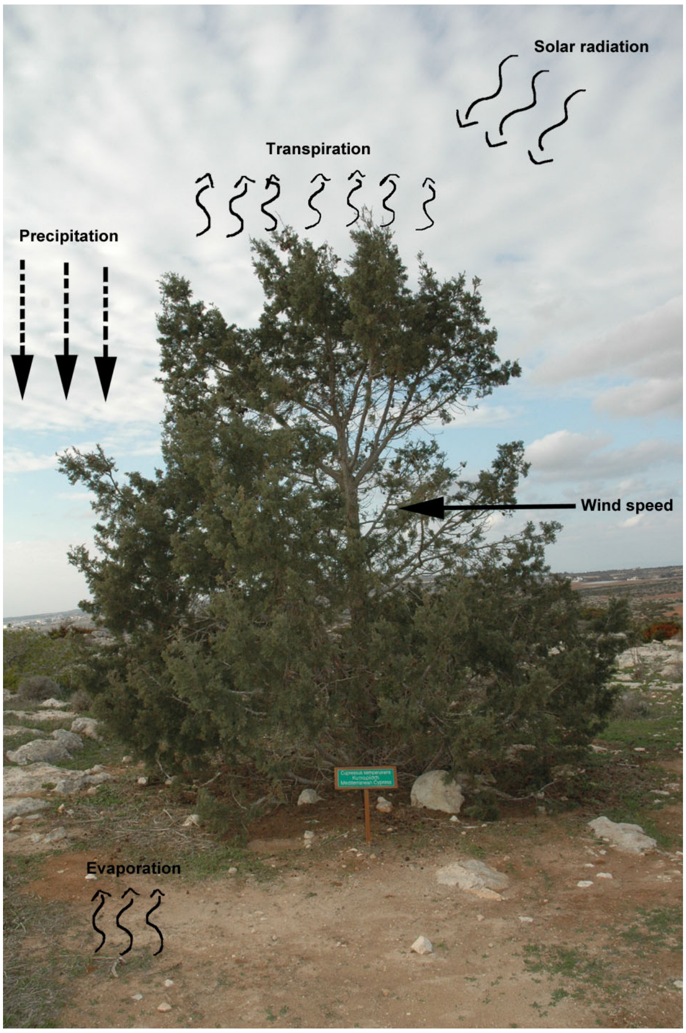

Figure 5.7: Evapotranspiration is a combination of the transpiration of plants and evaporation of water (from bodies of water and soils). The water comes from precipitation and the rate of evapotranspiration is dependent on the amount of solar radiation (heat), wind speed (at 2 metres), relative humidity and air temperature.

evapotranspiration undoubtedly plays a role, it is becoming apparent that genetics is also very important (Piperno *et al.* 2002).

How plants take up silica is not completely understood, however there seem to be two mechanisms, genetic and environmental and plants use both.

In genetic uptake, certain cells in plants are 'programmed' to take up silica, including epidermal short cells and hairs (Madella and Lancelotti 2012, Madella *et al.* 2009). Other cells, such as stomatae and epidermal long cells, take up silica due to environmental conditions, i.e., high evapotranspiration and water availability (Madella and Lancelotti 2012, Madella *et al.* 2009). Genetically controlled deposition of silica and formation of phytoliths will occur regardless of climatic and environmental conditions, however, environmentally controlled deposition is dependent on water availability and the amount of monosilicic acid in the soil (Madella *et al.* 2009; p. 33). This is the principle behind the Fs index (water stress) and the Madella *et al.* (2009) irrigation ratio. If there is an increase in moisture then there should be an increase in the numbers of environmentally-controlled phytoliths.

Another explanation of the mechanisms of silica uptake is active versus passive uptake as discussed in Piperno (2005; p. 9). Essentially, the plant expends a certain amount of energy to take up the monosilicic acid, which is then deposited into specific cells (Piperno 2005; p. 9). This is broadly equivalent to genetic control. In passive uptake, there is a 'close relationship between the movement of water and the amount of silica the plant eventually solidifies' (Piperno 2005; p. 9). In experiments, this has been demonstrated (Jones and Handrek 1967, Piperno 2005). This would be the equivalent of environmentally controlled uptake.

Soil chemistry may also impact phytolith formation. While it has been argued that high alkalinity may lead to increased dissolution of phytoliths (Cabanes *et al.* 2011; p. 2481, and see discussion below), there may be another reason why fewer phytoliths are found in certain contexts, especially offsite ones. If there is high alkalinity (pH 8+), coupled with high levels of sesquioxides (ferric oxides [Fe_2O_3] and aluminium oxides [Al_2O_3]), there is less silica available for the plants to take up (Raven 1983). This is because the sesquioxides absorb the silica ($Si(OH)_4$) (Raven 1983). If there is less silica, fewer phytoliths are produced. This could be an issue where terra rossa is abundant, which includes many limestone areas in the Near East. Terra rossa, a reddish soil (due to haematite content) is very alkaline, because of its parent material of limestone, and contains high levels of sesquioxides (Darwish and Zurayk 1997, Aydinalp and Fitzpatrick 2009). However, the presence of sesquioxides does not preclude phytolith formation.

5.3.2 Taphonomy

Although silica is a very robust material, it, and by extension, phytoliths, is still affected by taphonomical issues. The quality of phytolith preservation can be dependent on a variety of factors, including mechanical destruction (through transport of sediments and grinding of grains during processing) and well as chemical dissolution due to soil and sediment chemistry. Fire, too can have an impact in terms of colouration (Parr 2006). In some cases, the phytoliths may not be well preserved and so difficult to identify and quantify. However, the taphonomy of the phytoliths, especially those from offsite contexts, may give some interesting information regarding the presence of land surfaces. In the course of this research, it became clear that the state of preservation may provide some clues, and as such, very general criteria were developed to help determine the presence (or lack of) land surfaces. It should be noted that this part of the research is nascent and certainly needs development. At the moment, it is very general, and is used only to help provide possibilities that can be explored at a later juncture.

Unfortunately, to date there has been very little research into taphonomical issues in phytoliths, with exceptions such as Jenkins (2009) and Madella and Lancelotti (2012). This may be that the understanding of the underlying phytolith formation processes are still imperfectly understood (see discussion above). As such, if the underlying principles are not well understood, then it is difficult to gauge exactly how and why phytoliths dissolve, particularly in the biogeochemical detail. And sometimes, it can be difficult to distinguish between dissolution and incomplete silicification (as Cabanes *et al.* 2011; found when looking at 'weathered' phytoliths – these could be found in fossil assemblages as well as ashed reference samples, which would not have undergone any natural dissolution processes). As Jenkins (2009) points out, better understanding of this topic is needed as preservation of the assemblage affects interpretations.

Dissolution and fracturing

Once deposited into the soil or archaeological sediment, phytoliths are subject to both mechanical fracturing and chemical dissolution (see Figure 5.8). Fracturing can occur because of natural processes such as fluvial erosion and deposition as well as by human agency, through processing of grains for instance.

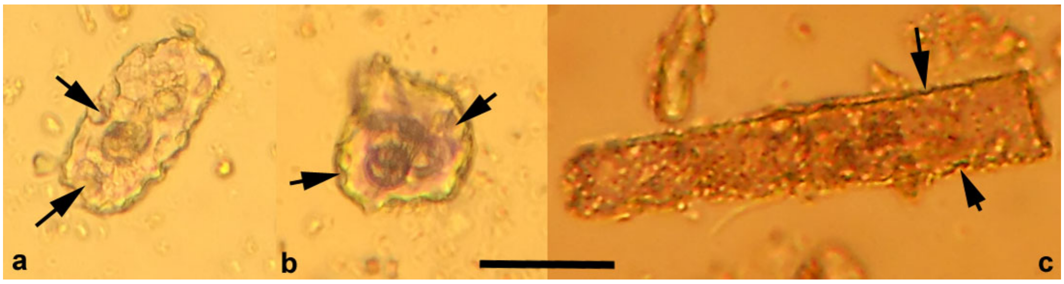

Figure 5.8: Examples of fracturing and dissolution. (a) and (b) both show fracturing that is typical of impact (such as moving downstream and coming into contact with other minerals); there will also be some chemical dissolution. (c) shows a long cell, which has been affected more by chemical dissolution (the sides look 'eaten' away); there is some minor fracturing as well. Bar is 10 micrometers.

Dissolution, normally caused by soil chemistry and the silica cycle in soils, can exacerbate this situation, weakening the phytoliths and making them more prone to breakage (Cabanes *et al.* 2011). Processing and perhaps even storage of sediment may also impact fracturing and dissolution of phytoliths. As such, the discussion will include first 'natural' processes of dissolution and fracturing and then effects on phytolith preservation from laboratory techniques. The robustness of phytolith types also plays a role: certain morphotypes are more robust and so better able to withstand various taphonomical processes (Cabanes *et al.* 2011). 'Ornamentation', such as projections on echinate and dentritic long-cells, are also prone to breakage and dissolution.

When the plant dies, the phytoliths are deposited into the top soil, the O horizon, which is very biologically and chemically active. This biogeochemical activity has an impact on the preservation of the phytoliths. As mentioned above, $Si(OH)_4$ is made up of silica from dissolved rocks as well as 'biologically deposited' silica – this includes the silica of opal phytoliths. The amorphous silica of less stable phytoliths is dissolved back into silicic acid (Alexandre *et al.* 1997), which is then taken up by plant roots, to produce another generation of phytoliths (Fraysse *et al.* 2009). Most of this dissolution takes place during 'leaf degradation' (Madella and Lancelotti 2012; p. 79), and can affect the majority of the phytoliths in the soil (Alexandre *et al.* (1997), p. 680: 'young, labile' phytoliths make up about 92.5 per cent of the phytolith pool and these are the ones that are most susceptible to dissolution, the rest become part of the subfossil assemblage).

The type of vegetation will have an effect on dissolution rates, for instance phytoliths are very quickly dissolved in forested environments (Madella and Lancelotti 2012).

Quick burial of these layers may help in preservation, however (Cabanes *et al.* 2011) so while the dissolution of the majority of phytoliths in the leaf litter is problematic, it may be somewhat mitigated in more 'active' environments, such as alluvial settings, where there is a potential of quick burials of O horizons. This process also helps to explain why far fewer phytoliths are found in soil / palaeosol deposits than in onsite contexts.

Although not a dissolution issue, phytoliths can also be translocated or illuviated down the soil profile to the B horizon where there is less biological activity and thus phytoliths will preserve better (Alexandre *et al.* 1997, Jenkins 2009). The phytoliths may also accumulate where there is a more clayey stratum (clay is less permeable), creating a sort of phytolith layer, which could be mistaken for a land surface (Alexandre *et al.* 1997). However, Madella and Lancelotti (2012; p. 78-9) state that it is not yet clear how much this process of illuviation actually affects the phytolith assemblage and it may be dependent on the soil type. In addition, they say, bioturbation also needs to be considered, as this can have a significant impact in some contexts. In any case, translocation, via water or biological activity needs to be taken into consideration (Madella and Lancelotti 2012). It may be difficult to differentiate between this and a rapidly buried soil horizon, and one issue arising from this is that the phytolith assemblage of a translocated layer may be less representative than that of a rapidly buried soil horizon.

Mechanical fracturing, due to natural processes or human activity can also impact the phytolith assemblage, identification of morphotypes and increase dissolution rates. Phytoliths can be eroded (i.e., transported) to other areas, via wind or water action (Madella and Lancelotti 2012). As with any rock, phytoliths when transported will be fractured, chipped and otherwise damaged. Furthermore, dissolution can occur while the phytoliths are being transported by water (water, filled with cations and anions, is the key element in many types of chemical weathering: Boggs (2001)). This fracturing and dissolution can impede identification of the cells, but more importantly, could help to separate phytoliths which have been transported, from those which have been deposited *in situ*, in off site contexts. This will be explored in more detail below. On site, phytoliths can be transported and damaged due to human activities such as sweeping (Madella and Lancelotti 2012). Mechanical disaggregation can also occur because of processing of grains: silica bodies, or multicells, can be broken down as crops are processed and/or pounded (to separate the husk from grain for instance: Albert and Portillo (2005)).

Mechanical fracturing and dissolution is, however, not limited to what happens when the phytoliths are deposited in on site or offsite contexts. Laboratory procedures may also play a role. Jenkins (2009) and Shillito (2011) conducted experiments on modern and archaeological assemblages respectively, to try to ascertain the effect laboratory procedures on phytolith preservation, particularly multicells.

Jenkins (2009) compared the number of multicells (wheat) preserved in two types of ashing methods (dry and acid or wet). What she found was that there were fewer multicells using the acid extraction technique (which involves acid digestion with hydrochloric acid (HCl) and nitric acid ($HN0_3$)). It should be noted that phytoliths from 'fresh', i.e. modern, samples are more soluble than fossil ones (Cabanes *et al.* 2011; p. 2484). As discussed above, the phytoliths that are preserved in soils and sediments are those that are more robust and/or rapidly buried and which haven't been dissolved back into soluble silica because of soil formation processes. Although the methods that Jenkins tested do not exactly match those methods employed here, it does show that acid digestion plays a role in disarticulating multicell phytoliths which in turn can have an impact on interpretation.

Shillito (2011) tested three methods on fossil assemblages of wheat to assess the impact of these methods on multicells. The three methods included smear slide (placing some sediment straight onto a slide), phytolith extraction, similar to Rosen (2005) and micromorphological thin section. She found that there were fewer multicells in the phytolith extraction method, and again acid digestion seems to be an issue. She also noted that multicells already started to disarticulate when being sampled (which could be seen in the thin sections: p. 637). However, the three methods tested are used to answer different types of archaeological questions, and in the end, the difficulties presented by all of the methods will need to be overcome.

The one issue however, is the acid digestion process. The method employed here (ie, Rosen 2005), uses one step of acid digestion: 10 per cent HCl. Other methods, however, add an additional digestion step and use a more concentrated form of HCl (3N HCl and 3N $HN0_3$: Albert and Portillo (2005). Looking again at Jenkins' results of wet ashing, which utilises both of these acids, it would seem that there would be an even greater impact on multicell disarticulation. The issue of acid digestion and dissolution has also been highlighted in diatom studies, and there have been similar results as diatoms are made up of the same silica material (Barker 1992).

Another problem may involve the sieving process. In the protocol used here, the sieving of dry sample is done prior to any clay separation and acid digestion. Often times, particularly in offsite samples, there is a high fraction of muds (silts and clays) which can dry in rock-hard clumps. These clumps need to be separated, through gentle grinding in a mortar, and this may lead to disaggregation of silica skeletons. In fact, some disaggregation and fracturing could occur as the sediment dries. Straub (1993) found that there was a significantly higher proportion of diatom fragmentation in dried samples than in wet samples. I found similar results in my own analyses of diatom samples from Lago di Pergusa (Marsh 2007). Similar fragmentation could be occurring with phytoliths, especially silica skeletons and more delicate forms of single cells (such as dentritic longcells where the dentritic ends can be fragmented). On the other hand, furnacing fossil assemblages appears to have no effect on the preservation (although it does affect fresh samples: Madella and Lancelotti 2012).

Madella and Lancelotti (2012; p. 81) do make a very good point: '[s]tandard laboratory procedures and the careful control over human errors that can be attained in a laboratory environment should result in phytolith assemblages that are, if not unbiased, at least all affected by the same errors'.

If what is left is a small fraction of what was originally there, then what makes a well preserved assemblage? Different parameters have been suggested. Cabanes *et al.* (2011) suggest that if more delicate phytoliths, such as papillae are present, this could indicate a better preserved assemblage. However, they go on to say that this could also be context driven: papillae are from the inflorescence (i.e., husks) and may not be present in certain contexts ((Cabanes *et al.* 2011) such as where fodder (stems, cereal straw) is stored, or where there might be bedding. Madella and Lancelotti (2012) suggest comparing proportions of long cells and short cells present. Short cells, such as rondels, are more robust and thus preserve better than long cells. Thus if there are more long cells than short cells, this could indicate good preservation (Madella and Lancelotti 2012).

5.3.3 Land use markers: located land surfaces

Analysis of onsite samples can give much information regarding resource and crop use. From the analysis, what could have been grown locally and what could have been procured locally can be inferred. There may even be a glimpse in terms of changing agricultural strategies, vegetation changes and indirectly, climate and environmental change. The analysis of offsite samples can help to confirm the inferences made from the analysis of onsite samples. As discussed above, offsite samples are not without its problems. Taphonomical issues play havoc on the preservation of assemblages and so can be difficult to use. In investigating whether or not land surfaces can be detected, this study does not look at annual inputs or duration *per se* – the land surfaces may indeed represent a palimpsest of years. This idea of 'inheritance' is not new: Fredlund and Tieszen (1994) discuss how soil processes take time and that layers will contain an accumulation of phytoliths (see also Neumann *et al.* 2009, Stromberg 2004).

However, in order to differentiate between land surfaces and B horizons or underlying sedimentary layers, the characteristics of the depositional (and sometimes erosional) environment and the source of the phytoliths needs to be understood.

Both sites are located in alluvial plains, which are generally thought of as being active environments (i.e., where deposition and erosion is fairly continuous), they, however, also have extended periods of stability (as discussed above). Sediments are deposited on the plain by the river(s) and sometimes are eroded away via channel cutting and increased flooding. The sediments which are deposited will also contain phytoliths from various parts of the river's catchment area.

During periods of stability, soil formation commences and plants grow on the plain: these can include riparian galleried forests, wetland plants, wild grasses, and of course, cultivated cereals and other crops. As these plants decay, they will deposit phytoliths into the top soil (leaf litter zone). In addition, phytoliths may also be transported via aeolian processes; this is particularly important in open landscapes (Neumann *et al.* 2009), such as alluvial plains which are cultivated or contain more grasslands. Any phytoliths transported by wind are difficult to quantify and will therefore be generally, though not completely, left out of the discussion. However, their input needs to be kept in mind as there may be some bias.

As such, phytoliths can enter the offsite record in a number of ways – in situ deposition, and via water and wind. Gravity can also have an input, via mass wasting and soil creep, however, in these study areas, colluvial type material plays a minor role. In essence then, there are two signals that can be detected: local, *in situ* (land surfaces) and regional signals (in alluvial sediments) (Neumann *et al.* 2009, Delhon *et al.* 2003), i.e., soil phytoliths versus alluvial sediment phytoliths (see Delhon *et al.* 2003).

But in order to differentiate between alluvial sediments, land surfaces and B horizons, some criteria must be developed. These are very broad and constitute a work in progress.

Alluvial sediments

1. Phytoliths will likely show signs of reworking from transport, including fracturing and 'hollowing out' (Zucol *et al.* 2005; p. 39; see Figure 5.8, (a) and (b)). When sediment clasts are transported via water (and wind), they get chipped, can be fractured, and if transport distance is long enough, can eventually have 'rounded' or abraded edges (Rapp and Hill 1998). In the case of the alluvial

sediments, if the transport distance is shorter then the fractured phytoliths may not exhibit much roundness, but rather be more angular. However, depending on transport distance (that is, from the foothills versus another part of the river plain), there may be an increase of breakage (Zucol *et al.* 2005). Velocity of the river stream power will also have an impact on breakage and chipping (Zucol *et al.* 2005). Unfortunately, as Zucol *et al.* (2005; p. 40) point out, 'no in vitro predictive model has been proposed that would enable us to determine the agent and degree of transport supported by a phytolith'. Measurements of breakage and angularity, for instance, may enable us to determine the origin of the phytoliths and thus enable us to extract more information regarding adjacent or catchment area microenvironments. This, as will be discussed in the concluding chapter, would be an interesting avenue of research.

2. Phytoliths will likely show signs of additional weathering. Fractured phytoliths are also more prone to chemical weathering (that is, dissolution by the cations in water) and as such may exhibit a greater degree of dissolution than complete specimens.

3. Identified phytolith numbers may be low. Many of the phytoliths will have been broken to such a degree that they become unidentifiable (see also Madella and Lancelotti 2012). Many of the offsite samples in this study consisted of very small fragments of silica, some of which were made of biogenic silica (see Figure 5.9).

4. There may be some freshwater diatoms and sponge spicules present, however these emicrofossils can also be present in other environments, such as lakes, and so should not be taken as conclusive proof by themselves..

Land surfaces / *in situ* phytoliths

1. Land surface phytoliths will likely exhibit much less fracturing and chipping than alluvial sediment phytoliths (although some more fragile specimens will have some), however there may be evidence of dissolution (chemical weathering) depending on taphonomical conditions (see above). Since transport distance is not a factor, fracturing should be less, however, other mechanisms in soil formation including bioturbation may impact preservation.

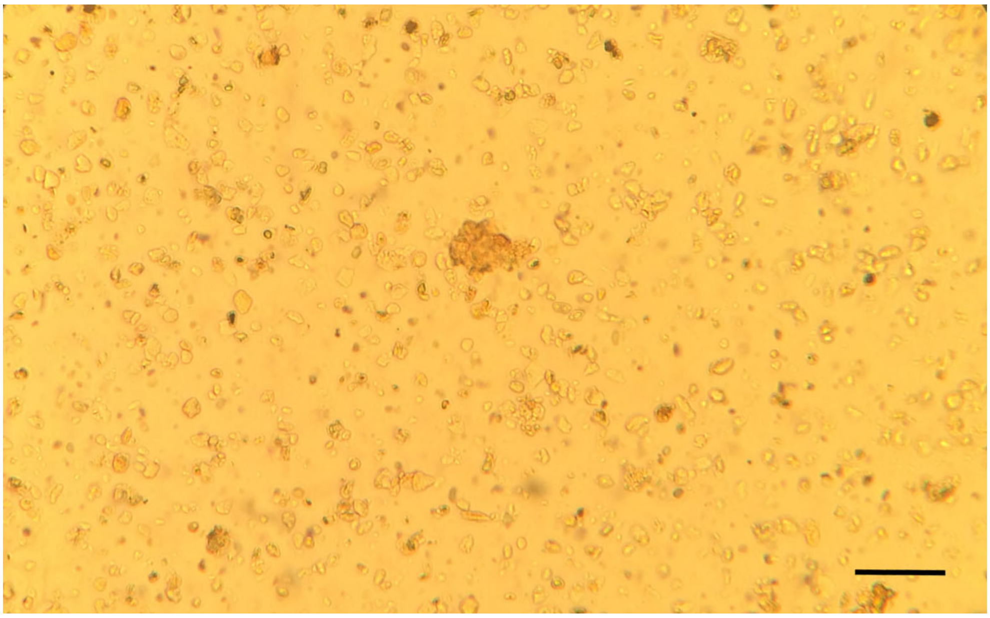

Figure 5.9: View of an offsite sample from the Shahrizor. Many of the offsite samples contained mainly small fragments of silica, with no identifiable phytoliths or other microfossils. Bar is 10 micrometres.

2. There should be a higher number of phytoliths per gram, although this will be dependent on speed of burial and taphonomical conditions (again see above).

3. There may be multicell phytoliths present, as well as larger, articulated specimens of sponge spicules, as well as diatoms (depending on the environment).

B horizons

These horizons may be superficially similar to land surfaces. Some may also exhibit a level of fracturing and chipping due to translocation (although how much this affects phytolith assemblages is not well understood (Madella and Lancelotti 2012). There may be a peak in phytolith numbers, for instance, if there is a clay layer, where phytoliths accumulate (Alexandre *et al.* 1997).

It should be noted however, that land surfaces and B horizons may also contain some reworked phytoliths. For instance, Neumann *et al.* (2009) found reworked Pleistocene period phytoliths in early Holocene layers. Often, transported sediments consist of older, reworked soils from the foothills – soils which of course contain phytoliths. These older soils, while being transported, are then considered sediments, or sometimes 'pedo-sediments' (Aydinalp and Fitzpatrick 2009). Once deposited, soil formation processes may commence, plants grow and die and deposit new phytoliths.

Once differentiated, if possible, different interpretations can be developed. Alluvial sediments containing reworked phytoliths can give information regarding catchment area vegetation change, microenvironments and perhaps even hint at cultivation taking place in adjacent areas of the floodplain. In terms of *in situ* phytoliths from land surfaces, we may be able to obtain information regarding agricultural strategies, local vegetation changes through time, and possible indirect evidence of climate conditions. B horizon samples may give similar information as land surfaces, albeit with weaker signals. It should be noted that this is conjectural at this stage and a more robust methodology will be developed in the future. For this thesis, any conclusions regarding *in situ* versus transported phytoliths remain tentative.

5.3.4 Irrigation

Irrigation, meaning both floodwater farming and channel irrigation, is a somewhat contentious issue.

In 1994, Arlene Rosen and Steve Weiner published a paper proposing that multicell size of cereals could be an indication of irrigation (Rosen and Weiner 1994). They laid out certain criteria: if there were 10 per cent or more 10+ conjoined cells, or any multicells containing more that 100+ cells, then this was indication of irrigation (Rosen and Weiner 1994; see Figure 5.10). In essence, when there is more water available and thus more soluble silica available for plants to take up, this in turn could lead to the formation of larger multicells, i.e., an increase in the number of conjoined cells, especially in the more semi-arid regions of the Near East, where there is a higher rate of evapotranspiration.

Several authors, including Jenkins *et al.* (2011) have raised issues with this, not so much in terms of the potential for larger multicells or water availability, but rather in terms of extracting those multicells and potential disarticulation (via extraction or onsite activities such as grinding: Shillito 2011, Albert and Portillo 2005). In other words, a lack of larger multicells does not necessarily

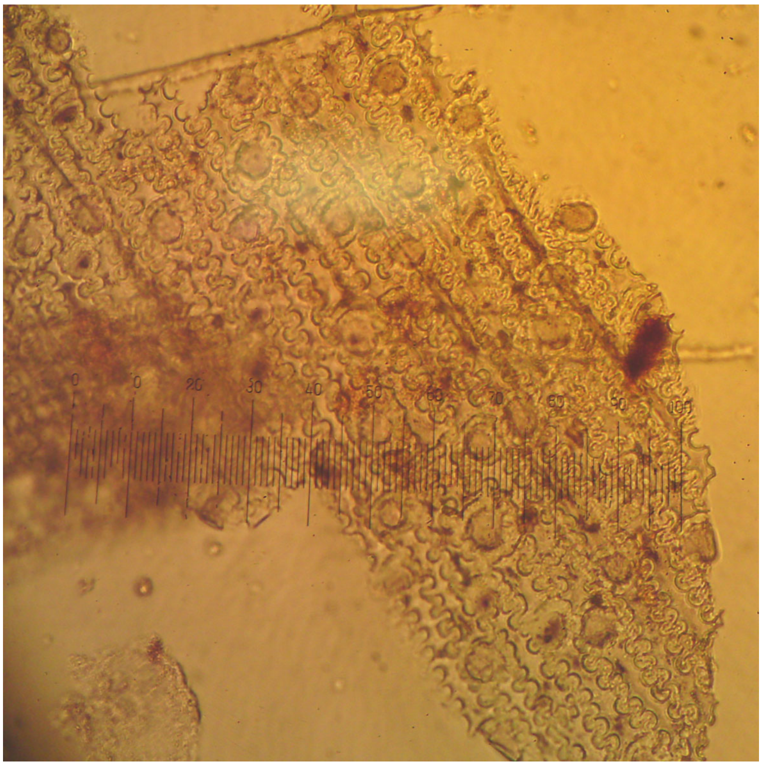

Figure 5.10: Emmer wheat multicell from Hirbemerdon Tepe, containing 100+ conjoined cells

preclude irrigation.

However, Jenkins *et al*'s (2011) work tests for indications of channel irrigation, the type practised in the more semi-arid regions such as southern Mesopotamia and parts of the Khabur, where rain fed agriculture is not possible. A more useful way to approach this issue may be looking at the question of water availability, whether it comes from flooding of plains by rivers or through channel irrigation. Rain water is not considered by some researchers as a real source of increased multicell size as there is little silica in rain water (Jenkins *et al.* 2011).

Madella *et al.* (2009) compared the numbers between 'fixed' phytoliths (i.e. those genetically produced – see above) and 'sensitive' forms (i.e. those produced because of the climate) in order to see if there were any differences due to increased water availability. The theory is that if there are more 'sensitive' forms, then there must be an increase of water availability, via irrigation. Although they refer to rainfed versus irrigation farming in more arid areas and also comment that there are differing results across cereal species, there is potential in for this method, particularly in areas such as southern Mesopotamia or time periods that are known to be much more arid.

It is particularly important to understand if and when channel irrigation was used in the Near East as it gives information on climate and environmental change, intensification and so on. Unfortunately, there is very little other evidence for prehistoric irrigation, for instance, in the form of structures, although some structures have been found for later periods (Jenkins *et al.* 2011), mainly for larger scale projects. So evidence must be found elsewhere. But to appreciate the contribution of phytoliths to this debate, we must understand its limits and look at the phytolith data in a number of ways and combine this with other datasets, such as sediments, macrobotanical remains, weed ecology (see Jones *et al.* 2005; 2010), and archaeological evidence.

A combination of information from phytoliths can be utilised. For instance, the Fs ratio (see below) can be used to look at potential water availability. In addition, numbers of larger multicell phytoliths (10+) can also be calculated. The presence / absence of certain phytoliths such as jigsaws and *Setaria* sp can also yield information. Jigsaws are formed in the leaves of dicots and need a certain level of water availability. The presence of the morphotypes can either signify nearby wet forest conditions or possibly channel irrigation (Tsartsidou *et al.* 2007). *Setaria* sp. may also be an indicator of channel irrigation (Prof AM Rosen, pers. comm.).

A general idea of climate variability in the Holocene in the Near East has been developed (see Chapter 2) and sedimentary evidence can give localised indications of whether the rivers were alluviating or incising at certain points in time. When there is a certain level of precipitation (and not too much deforestation), then rivers will be alluviating regularly, and this will be reflected in the sedimentary record. If this is the case, then any possible indications of increased moisture can be linked to higher precipitation and river discharge. On the other hand, an incising river reflects drier (relatively) conditions. There will be no regular deposition, although there may be evidence of high energy flooding (with sediments exhibiting poor sorting of grains). If there is evidence of increased moisture in a local area, this could be an indication of channel irrigation.

5.3.5 Indices

Other indices may also be useful in looking at climatic conditions and changing vegetation patterns. Different morphotypes can be used in comparison to see if there are changing values that could reflect changing climate, environment or vegetation. Before discussing the different indices, a brief discussion of C_3 versus C_4 plant morphotypes and photosynthetic pathways is warranted.

C_3 and C_4 pathways

There are different short cells produced by grasses, however, similar morphotypes are produced by a range of grasses (Twiss 2001; see Figure 5.11). There are some general rules that can be applied. Quadralobes (crosses) and bilobes (dumbbells) are mainly produced by panicoids. These are C_4 tall grasses, which prefer mesic environments (warm and wet) (Alexandre *et al.* 1997, Twiss 1992). They can also indicate high moisture availability (Bremond *et al.* 2005). Saddles are mainly produced by chloridoids, C_4 short grasses which prefer xeric (warm and dry) conditions (Alexandre *et al.* 1997, Twiss 1992) or dry soils (Bremond *et al.* 2005). Rectangular and circular shaped phytoliths such as rondels are produced by C_3 festucoid (pooid) grasses, which prefer more temperate conditions (Alexandre *et al.* 1997, Twiss 1992, Bremond *et al.* 2005). Festucoid grasses include cereals.

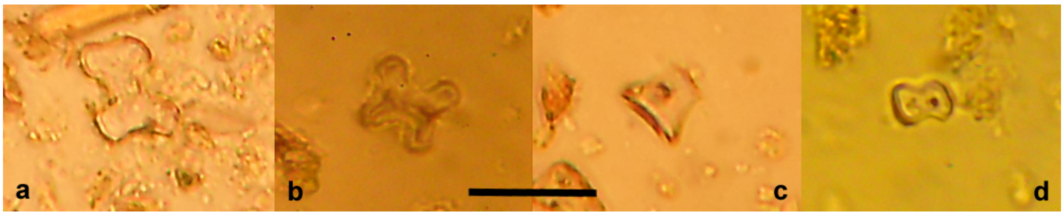

Figure 5.11: Short cells produced by grasses: (a) bilobe, (b) quadralobe, (c) rondel and (d) saddle. Bar is 10 micrometres.

The photosynthetic pathways are adapted to temperatures. The following descriptions are taken from Twiss (2001).

The C_3 pathway (Calvin-Benson cycle): CO_2 enters the leaf via the stomata and moves into the mesophyll where there are chloroplasts. CO_2 is 'catalysed' into phosphoglyceric acid (PGA) which has three carbon atoms.

The C_4 pathway (Hatch-Slack cycle): this pathway has an extra step. The CO_2 enters the mesophyll where it 'reacts' with phosphoenolpyruvate (PEP) and is transformed into oxaloacetric acid (OAA), which has four carbon atoms. Malic and aspartic acids are created and these then enter the bundle sheath cells and CO_2 is released and then 'catalysed' to make PGA.

Ic climatic index

Essentially this is the ratio of C_3 pooid grasses versus C_4 chloridoids and panicoids (Burrough *et al.* 2012, Twiss 1992, Barboni *et al.* 2007). If C_3 grasses dominate, then the climate conditions are cooler, more temperate. Pooid morphotypes include rondels and polylobes, C_4 morphotypes include C_4 bilobes, saddles and quadralobes (Barboni *et al.* 2007). One caveat to bear in mind is whether or not the phytoliths are in situ or reworked, thus these could be either local conditions or more regional ones. As Burrough *et al.* (2012) advise, this index should be used with caution and it should be understood that only broad conclusions are reached.

Iph aridity index

This index measures the degree of aridity (at a given time). It was originally used in marine cores (Alexandre *et al.* 1997). It calculates the number of saddles divided by saddles + crosses + dumbbells (Alexandre *et al.* 1997). If the percentage is over 40 per cent, then dry grasslands are indicated (Alexandre *et al.* 1997). The same caveat as above applies.

D/P tree cover index

The D/P ratio is used to differentiate between grasslands (P = poaceae) and tree cover (D = dicotyledons) (see Alexandre *et al.* 1999; 1997, Bremond *et al.* 2005). It is used more successfully in tropical areas (in the ITCZ zone) where dicotyledons tend to produce more verrucate (rough) spheroids (Alexandre *et al.* 1997). However, other authors have used it in other areas outside of this area, for example, Delhon *et al.* (2003) in the northwest Mediterranean area, and readjust the ratios downward to reflect the lower number of spheroids. Values for tropics are about 1.82 to indicate tree cover (Bremond *et al.* 2005) and more than 0.1 to indicate broadleaf tree cover in NW Mediterranean area (Delhon *et al.* 2003). Decreasing values can be reflecting the opening up of forests (Alexandre *et al.* 1997, Stromberg 2009).

The morphotypes used in the ratios do vary from author to author: Bremond *et al.* (2005) use rough sphericals / bilobes + quadralobes + saddles + rondels + polylobates + tricombe + keystones; on the other hand, Barboni *et al.* (2007) include smooth spheroids in their dicot counts. Although there is some controversy regarding smooth sphericals, as they are produced by both monocotyledons and dicotyledons, they argue that these morphotypes are mainly produced by dicotyledons and so should be used (Barboni *et al.* 2007).

In the case of alluvial sediments, it needs to be determined whether the dicotyledons in particular are reworked or *in situ* phytoliths. If they are *in situ* and it is a land surface, then any tree cover could be indicating a riparian forest (local versus regional signals: Delhon *et al.* 2003). On the other hand, if they are reworked, then they could be signals for upland forests. The sedimentary evidence of regular alluviation versus flash flooding may be of use: if there is regular alluviation, then the uplands are likely to be vegetated.

Fs water stress ratio

Barboni *et al.* (2007) use this ratio to assess drought stress at a given time. It is the percentage of keystone bulliforms divided by grass longcells, the idea being that keystones are produced when plants experience 'drought stress' (Barboni *et al.* 2007; p.457-8); longcells are a sensitive form and produced when there is more water (Madella *et al.* 2009). Higher values indicate decreasing water availability.

In order to obtain somewhat robust statistical data, 200 or so diagnostic forms should be counted (per slide)(Stromberg 2009). This, of course, may cause the overall counts to be unobtainably high, so some compromise may have to be made (Stromberg 2009).

5.3.6 Onsite samples

Many of the indicators of offsite samples also apply to onsite samples. Single cells (short cells and long cells) and multicells (silica skeletons) are both useful for elucidating plant use behaviours on site (storage, processing, choice), plant availability and agricultural strategies. Monocotyledon (grasses, sedges, palm) morphotypes tell us what sorts of grasses, sedges and palms are present. For instance, rondels indicate the presence of C_3 pooid grasses (i.e., cereal grasses) (Tsartsidou *et al.* 2007, Twiss 1992) and bilobes could indicate the presence of panacoid grasses. As discussed above, these short cells can give information on environmental conditions and plant availability: the different morphotypes indicate whether they are C_3 or C_4 plants (Twiss 1992).

Dicotyledon single cells are also useful. For instance, polyhedrons, can indicate the presence of trees in the area (Bozarth 1992). Jigsaw-shaped morphotypes (which form in leaves) may be present, indicating wetter forest conditions or irrigation (Tsartsidou *et al.* 2007); the possible presence of irrigation provides further evidence of agricultural strategies.

Multicells can be identified to genus and sometimes even to species level (Tsartsidou *et al.* 2007). Rosen (1992) has developed a methodology for differentiating between barley and wheat (and identifying some to species level; see Figure 5.12), as well as agricultural weed grasses, based on the morphology of the long cell waves, frequency of papillae, ornamentation of the papillae and the shape of the cork cells (see also Tsartsidou *et al.* 2007). This is particularly useful for this study as changing barley/wheat ratios could be an indicator of changing agricultural strategies. Multicells also come from different parts of grasses (and other plants), some from the husk, some from the culm (stem), which can also be differentiated (see Rosen 1992). Ratios, presence and absence of these give information on behaviours and crop processing. The presence of

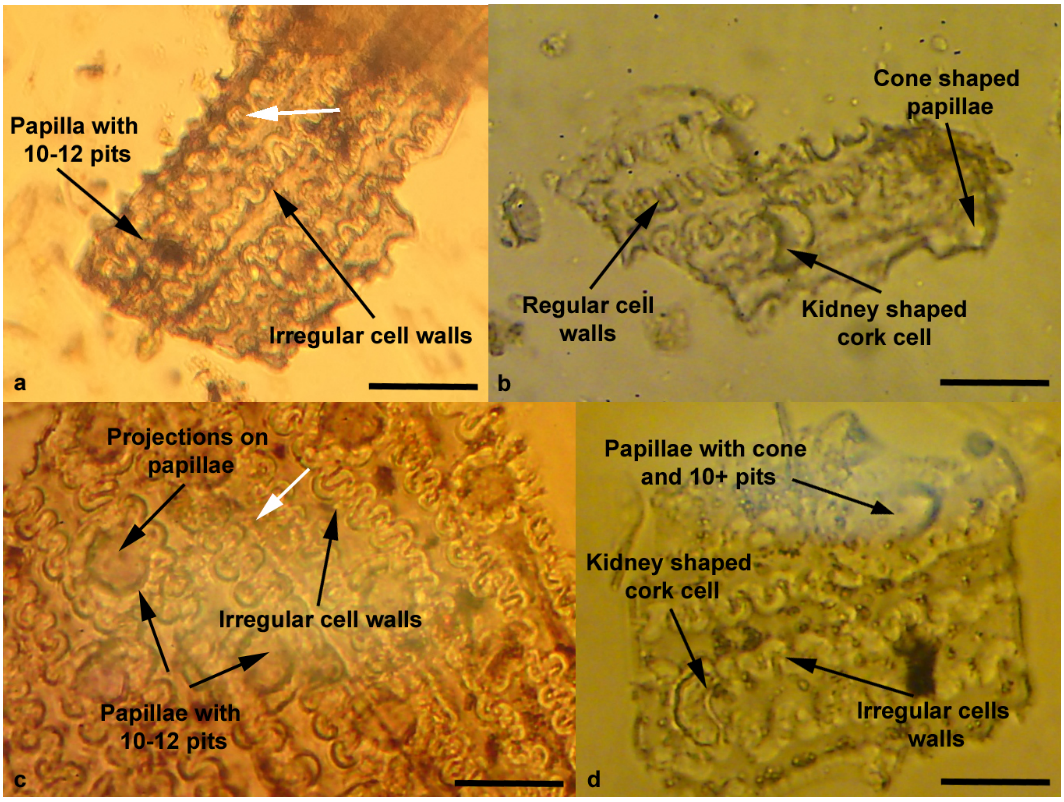

Figure 5.12: Cereal multicells: (a) possible emmer wheat from Bakr Awa. Wheat is usually identified by the number of pits around the papillae (10-12) and the irregular waviness of the cell walls. In this case, note the sometimes more regular form of cell wall (see white arrow); the more regular walls can be confused with barley. (b) Barley husk from Hirbemerdon Tepe. Note the cone shaped papillae, kidney shaped cork cell and more regular cell walls, all characteristic of barley. (c) Emmer wheat from Hirbemerdon Tepe. Note the number of papillae and that there are some regular cells walls (white arrow). Note also the protrusions on the papillae, also characteristic of emmer wheat. (d) Image of macaroni wheat (Triticum durum) from the UCL reference collection. Note the kidney shaped cork cell and cone shaped papillae, which can be confused for barley. Measurement bar is 10 micrometres

stems could indicate animal fodder or bedding and the presence of husks could indicate storage or crop processing (Rosen 1992, Tsartsidou *et al.* 2007).

Identifying different plants within archaeological and environmental contexts is beneficial in answering questions regarding agricultural strategies, decision making, risk aversion and environmental change. It is, however, not only decisions on what to grow that can be elucidated, but also decisions on how to grow crops, i.e., dry farming versus irrigation. The size of the multicells, as mentioned above, could indicate whether or not irrigation was practised (Rosen and Weiner 1994).

5.3.7 Methods

Protocol

The protocol is after Rosen (2005). An initial aliquot of circa 0.8g to 5g of sediment sieved at 0.5mm was used. The amount used was dependent on sample type (onsite versus offsite) and whether a high concentration of phytoliths was expected. Offsite samples normally require more sediment to be processed (see for instance Burrough *et al.* 2012). The sediments were placed into 50ml plastic test tubes and carbonates were removed with 10 per cent HCl and left to stand until they stopped fizzing. Distilled water was added to the tubes and they were centrifuged at 2000rpm for 5 minutes. The suspense was poured off. This was repeated two more times.

Clay was then removed, using a method of settling. The contents of the test tubes were decanted into tall beakers and sodium hexametaphosphate (Calgon) was added. Brita water was added to fill the beakers to a height of 8cm (it is the height that is important for settling velocities). The mixture was agitated for one minute and left to stand for one hour and ten minutes. The water with suspended clays was poured out and the beaker was refilled to the 8 cm mark and allowed to stand for one hour. This was repeated until the suspense was clear, signifying the removal of the clays. Timings and volume for settling had been previously calculated.

The sediment was then pipetted into fire proof crucibles and dried in a drying oven (at 40°C). This was followed by organic matter (OM) removal through furnacing at 500C for two hours. The dried sediment was put into 10ml plastic test tubes and sodium polytungstate calibrated to a specific gravity of 2.3, which is slightly heavier than the opaline silica phytoliths was added. The tubes were then centrifuged at 800rpm for ten minutes. The supernatant, containing the phytoliths, was poured into new 10ml test tubes and distilled water was added. The tubes were centrifuged, this time at 2000rpm for 5 minutes, and the suspense poured off. This step was repeated two more times. Afterwards, the phytoliths were placed into new glass beakers, dried and weighed. The phytoliths were then mounted on slides with Merck New Entellen.

Analysis

Once the slides were mounted, they were examined under a transmitted light Alphashot microscope at 400x magnification. The slides were scanned and phytoliths counted, 400 for single celled examples, 100 for multicells, if possible (some slides had few phytoliths). Both monocotyledons and dicotyledons were counted, and were documented in a counting sheet (see Appendix F). This is based on a counting sheet initially devised by Prof Arlene Rosen but now expanded to include subtypes of bilobes for instance as well as an expanded list of dicotyledon phytoliths. Many categories were not used in this study, and others were combined (such as psilate and sinuate long cells).

The phytolith data were then calculated on an Excel document (devised by Prof Arlene Rosen), so that number of phytoliths per gramme could be calculated (number per slide/mg mounted*total phytolith weight*total sediment weight*1000). Once the number of phytoliths per gram was calculated for each category on each sample, they were entered on a separate Excel sheet and graphed out as histograms (absolute counts and percentages). Multivariate analysis (principal component analysis) was also carried out on multicell phytolith data from offsite contexts in order to better understand the relationship (or lack thereof) between different vegetation types.

400 single cells and 100 multicells were the ideal minimum counts. Albert and Weiner (2001) showed that counting at least 265 phytoliths gave an error rate of 12 per cent. Also higher counts makes underrepresented plants more likely to show up (Stromberg 2009). In terms of indices, it was hoped that the selected minimum number may augment against counts not quite reached for certain phytolith types. It should be noted that counts were not achieved in most offsite samples, but in all onsite ones.

Indices

Different indices (see above) were calculated and include: Ic, Iph, Fs and D/P, as well as Rosen and Weiner's (1994) quantification for irrigation (water availability). The Ic follows Barboni *et al.* (2007), but with the inclusion of papillae in the pooid calculations as these are only formed in these grasses. Iph follows

Alexandre *et al.* (1997), Fs follows Barboni *et al.* (2007). For D:P, Bremond *et al.* (2005) was modified to include smooth sphericals with the dicotyledons (Barboni *et al.* 2007). (Barboni *et al.* 2007) also suggest including all tree phytoliths since not all trees produce spheroid morphotypes.

Nomenclature

Nomenclature followed to some extent, the International Code for Phytolith Nomenclature 1.0 as laid out by (Madella *et al.* 2005). In other cases, the more traditional names, such as rondel and papilla have been kept (considered to be *nomina conservada* in any case: Madella *et al.* (2005)).

Identification

Identification of single cell and multicell phytoliths were based mainly on the Near Eastern Phytolith reference collection housed at the Institute of Archaeology, UCL.

Part III

Results

Chapter 6

Results

6.1 Introduction

In this chapter, the results are presented. First, the geoarchaeological and phytolith analysis results from Hirbemerdon Tepe will be discussed. This will be structured as follows: the geoarchaeological results, including section drawings and sediment analyses will be shown. The phytolith analysis results will then be discussed, first with the offsite samples and then the onsite samples. Some of the data will be presented in the chapter, the rest, in particular the raw data, can be found in the Appendices. The Bakr Awa / Shahrizor section will follow a similar structure. The geoarchaeological and phytolith data from each site will combined in the discussions in Chapters 7 and 8.

6.2 Hirbemerdon Tepe

6.2.1 Geoarchaeology

Introduction

The geoarchaeological study of Hirbemerdon Tepe consisted of desk-based research, field survey and recording, sampling and laboratory analysis of river terrace sections and a small trench. The purpose of this study was to understand better the changing hydrology on a local and regional scale during the Mid- to early Late Holocene.

Survey

Although there are several good references on the structural geology of south-east Anatolia (Altini 1966, Tolun 1962, IEG 2001), the scale is often rather coarse (1:250,000 was the most detailed), and the easily accessible coverage of this area is cursory. As this area is rich in natural gas resources, it was difficult and very expensive to obtain more detailed geological maps for research purposes.

Topographical maps of the Diyarbakir region (1:100,000 scale), prepared by the Soviet military, were used in the initial analysis. The Ilisu Engineering Group's Ilisu Dam and HEPP Environmental Impact Assessment Report (IEG 2001) was also consulted, as was Google Earth and aerial photographs. In addition, Doğan (2005a; see also Chapters 3 and 7) has written on Quaternary sedimentation and archaeological sites in the Bismil-Batman region, just north of this study area, which was very useful.

With these sources, it was possible to obtain a general idea of the geology, topography and sedimentology of the region and to pinpoint any areas to be investigated further in the field.

It was clear from the aerial photographs, topographical maps and other resources that the local area surrounding the site is a small alluvial plain, in the foothills of the Taurus mountains. The Tigris incises into both the limestone bedrock and loose alluvial sediments of the terrace. The Tigris is also incising into the tell itself, not just the terrace, where the lower and outer towns (and as other sites) were located. A wadi was also identified (see Figure 3.10), which runs from the foothills, dissecting and eroding the terrace and running into the Tigris.

The survey encompassed a small area, *circa* 0.5 kilometre diameter surrounding the tell. The confines of the geoarchaeological survey area was limited by site permissions from the government.

The description of the geoarchaeological survey results is discussed in more detail in Chapters 3 and 7. Briefly: the geology and geomorphology was more complex than originally thought. In Tolun's (1962) map, Hirbemerdon Tepe is located on the Eocene limestone formation. However, the site seems to be at a geological juncture and consists of foothills which are made up of two types of formations: the Eocene limestone Midyat Formation and the Miocene Germick Formation, which is comprised of littoral and terrestrial sediments, resulting from tectonic uplift (the sea receded, and marine and coastal processes were replaced by terrestrial ones). The formations can be easily differentiated by colour and sediment type and are divided by a sharp erosional boundary (see Figure 3.7). It is important to understand the underlying geology in order to understand the unusual characteristics of the tell itself. The site was built on top of an outcrop, rather than on a Pleistocene terrace, and furthermore was built into the bowl-like feature contained within the outcrop (see Chapter 3).

Between the foothills is an alluvial plain, which undulates and consists of different terraces, dating from the Pleistocene (mainly seen as small hills in the distance – see Figure 3.8) to the Holocene. The cuts and erosion of the earlier Pleistocene terraces as well as deposition of later sediments were likely created by other rivers and wadis criss-crossing the plain and flowing into the Tigris, as well as the Tigris itself.

Other higher elevation areas could also be seen in the alluvial plain – further outcrops, marked by caprock dolines, which are crater-like features, similar to the bowl feature of the site (see Figure 3.9). These are covered by later alluvium.

At the edge of some parts of the terrace, next to the Tigris, there was severe erosion caused by pumped irrigation water running over the sides and into the Tigris. This caused sections of the terrace to collapse (see Figure 3.4). Although destructive to the banks and any archaeology contained within the terrace, they did prove to be useful as they provided two of the sections recorded and analysed (G01 and G02).

Section and trench observations

Two sections and one trench were recorded (drawn and photographed) and sampled for geoarchaeological and phytolith analyses (see below). Generally speaking, the sediments consisted of floodplain sediments, with mainly massive structure, although some had some cross-stratification; no channel cuts were seen and boundaries between layers were not very clear in many cases. The grain size, typical for alluvial floodplain sediments, varied from fine sands to muds (silts and clays) and there was some colour variation, although not particularly dramatic.

Laboratory analysis

The samples discussed here come from the terrace area next to the tell (see Figure 6.1). In this terrace, both the outer and lower towns were located. The samples came from three areas: a trench (T01) and two sections in the terrace bank (G01, G02). The samples were subjected to a variety of analyses. These included: sediment description, grain size analysis, magnetic susceptibility, loss on ignition (LOI) and spot phosphate analysis (Gundlach method). Further statistical analyses were carried out on the grain size results: mean grain size, standard deviation, skewness and kurtosis. The statistical formulae and data can be found in Appendix B, sediment descriptions in Appendix C, grain size histograms in Appendix D, and other analyses results in Appendix E.

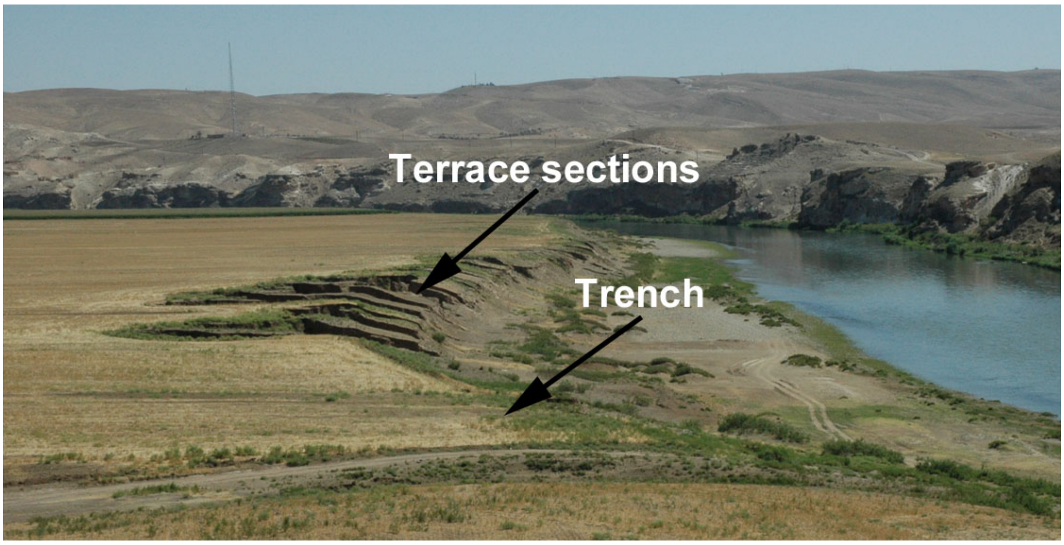

Figure 6.1: Approximate locations of the trench and terrace sections

T01: Terrace trench

This trench was excavated close to the Outer Town. The stratigraphic section was described (see Appendix C), drawn and photographed in the field (see Figure 6.2 and Figure 6.3). Geoarchaeological and phytolith samples were then taken from the section and further described and analysed.

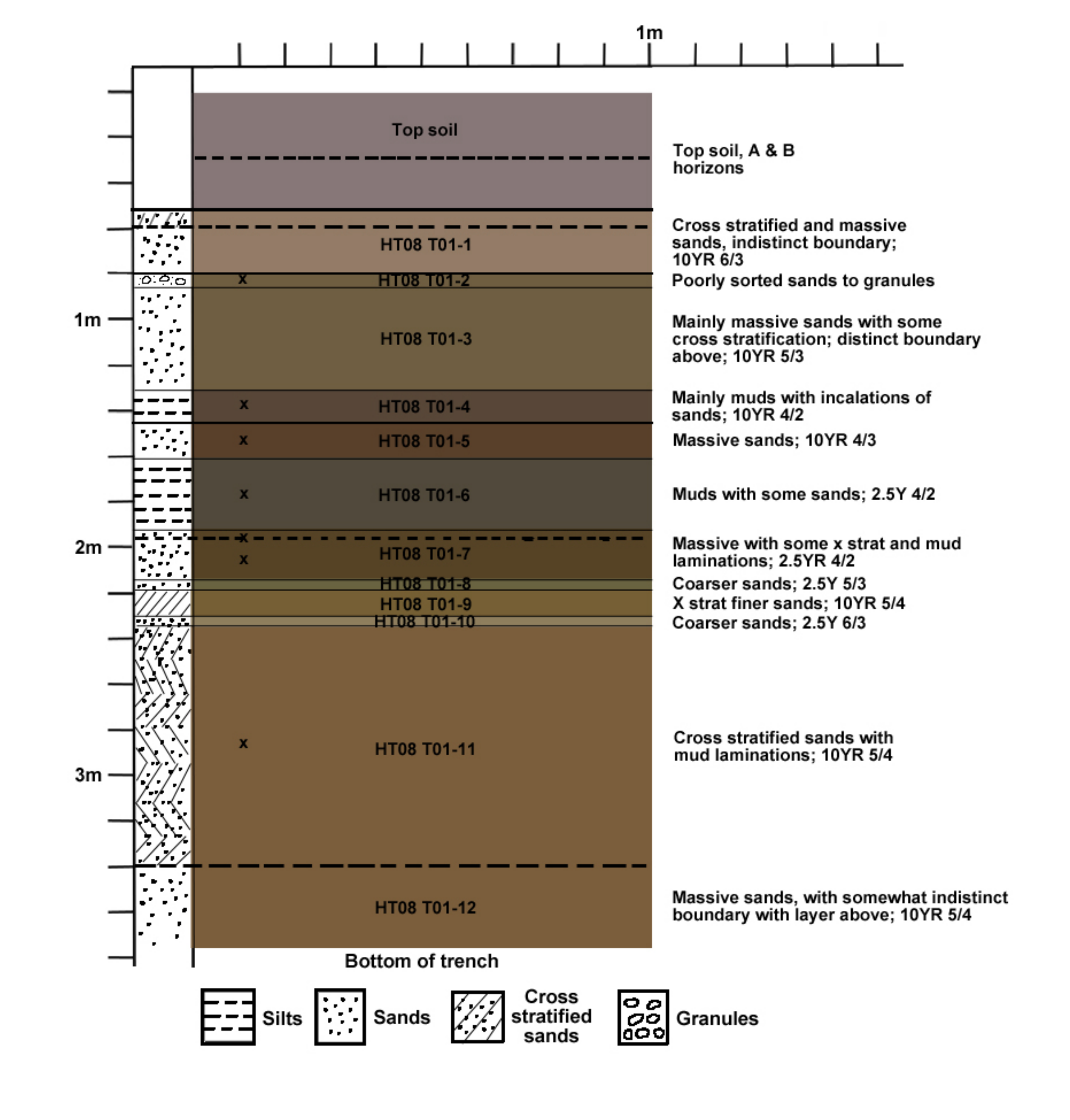

Figure 6.2: Section drawing of the terrace section. Samples are marked with an x. In most cases, phytolith samples were subsampled from the bulk sediment samples. However, in layer HT08 T01-7, a separate sample was taken from a mud lamination (see dotted line)

The terrace consists mostly of cycles of fine grained sands (massive and cross-stratified) and silts. The overall colour of the section was a yellowish brown, but there was some variation. From the bottom of the trench (T01-12) there were repeating cycles of yellowish brown (10YR 5/4) and olive brown deposits (2.5YR 3/3). From layer T01-6 upwards, in the middle of the section, the colours tend to range in the 10YR spectrum, from greyish brown to brown.

All of the samples analysed exhibited very poor sorting (according to standard deviation analysis), although they looked moderately well sorted in section. This sorting would have affected the mean grain size of the samples, often

Figure 6.3: Photograph of the terrace section. The section measures 1 metre by 4 metres

smaller than what was observed in the field. T01-11, for instance, consists of cross-stratified fine grained sands, but the mean size is coarse silt. But as mentioned above, these sediments consist mostly of silts to fine sands and there is very little difference in terms of size between them, and the sizes seem to intermix, i.e., sandy silts, silty sands.

One stratum, T01-2, towards the top of the section, stands out as it is coarser grained, consisting of a massive structure and poorly sorted sands to granules (in section). The mean grain size was also larger – fine sand. All of the samples also exhibited positive skewness (i.e., tending towards fine-grained). The kurtosis was also rather high (leptokurtic) indicating that there was good sorting. All of the samples were unimodal, however, had long tails (towards the finer grained spectrum), which could have contributed to the poor sorting results given in the standard deviation interpretation.

The magnetic susceptibility, loss on ignition and phosphate readings can be found in Appendix E. Low and high readings were taken before and after firing the samples (for LOI analysis). There was very little difference in the low and high frequency readings, both pre-fire and post-fire. After firing, all of the readings were reduced somewhat. Two readings do stand out, that of T01-2 and T01-11: both readings were over 200, higher than the other readings. The percentage loss of organics in the samples was minimal, all were 1 per cent. The phosphate readings were somewhat more variable: most were 1, but T01-4 had a reading of 3, and T01-5 had a reading of 2, suggesting that there is a slightly higher phosphate content in these samples.

G01: Terrace edge section

This section (see Figure 6.4 and Figure 6.5) reflects the top portion of the terrace; it can be correlated to the second terrace and trench sections (see Chapter 7), and one particular layer provides a relative date (*terminus post quem*) for part of this section. Sediment descriptions can be found in Appendix C.

The visible section is just over three metres in height. The bottom is obscured by poorly sorted colluvium, from the collapse of the terrace sides. Most of the layers are characterised by silty sediments. The sedimentary layers are covered by a unit of soil: modern alluvosol (33 centimetres). G01-2 (under the modern soil) and G01-4 (bottom layer) are both brown (7.5YR 6/3 and 7.5YR 5/2, respectively). Both of these layers contained some inclusions of gravels, the upper layer also contained fragments of roots. G01-4 also contained a thin layer of burning (see below and Chapter 7).

However, the middle layer, G01-3, stands out because of its colour and inclusions. It is a pinkish grey (7.5YR 7/2) and consists of silts with inclusions of pebbles and rocks, as well as artefacts (flint core and grinding stone). This particular layer can be seen in many of the exposed sections in the terrace edge trenches, even through the severe desiccation, because the colour is so different. In other sections, this layer contained coarseware and RBWW (red brown wash ware, in use from the EBA through the MBA), as well as possibly later pottery (see Chapters 3 and 7).

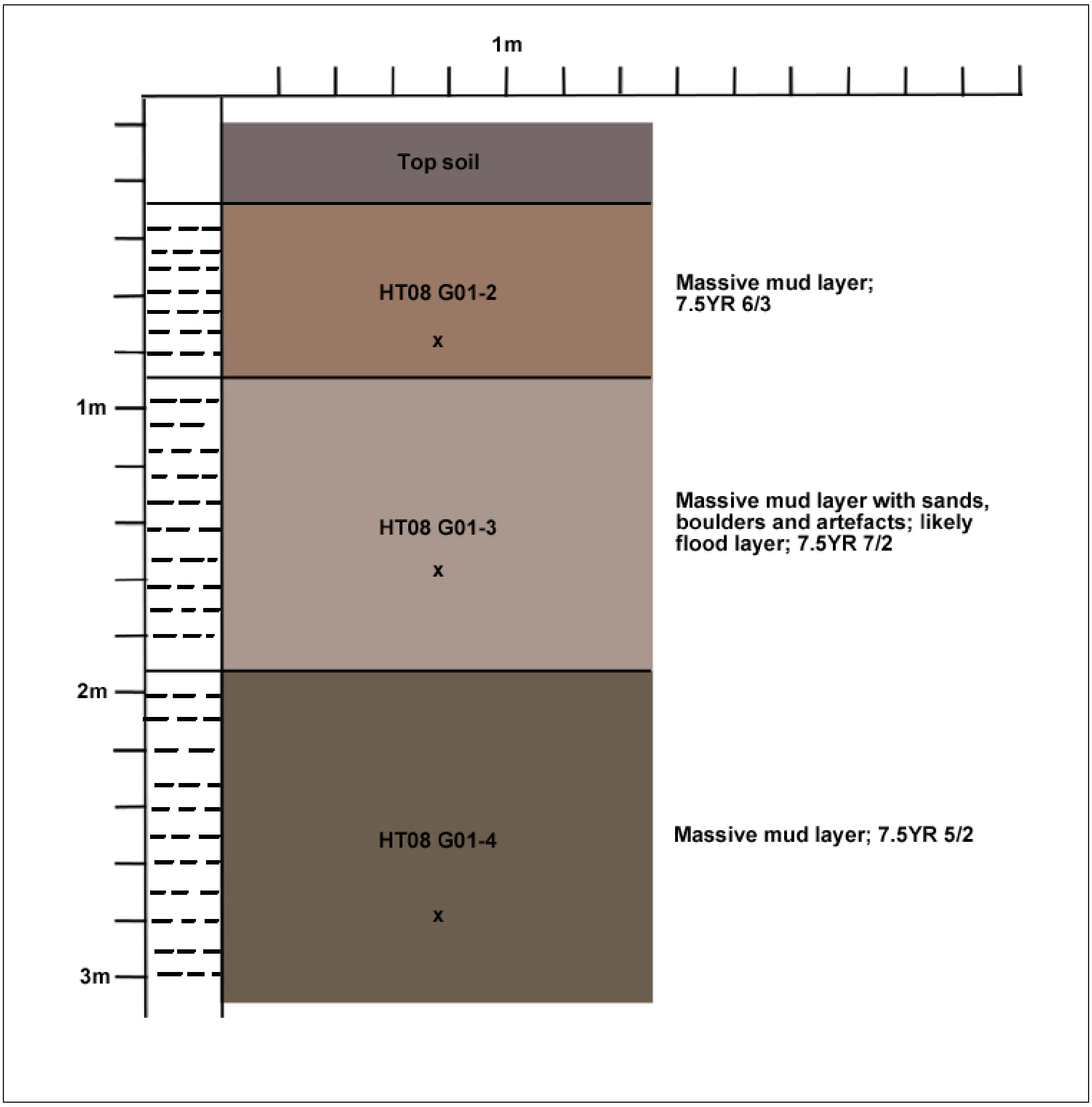

Figure 6.4: Section drawing of the terrace edge section G01. Samples taken are marked with an x, which were later subsampled for phytoliths

With the exception of the modern soil, all of the layers were sampled and analysed. The statistical and graphical results for all three were fairly similar.

According to the grain size histograms (see Appendix D), all are unimodal, but with long tails. The standard deviation indicates that all of the samples are very poorly to extremely poorly sorted. The mean grain size for G01-2 and G01-4 is medium silt, which tallies with the field description. However, the flood layer, G01-3, has a mean grain size of clay. This is probably to do with the nature of the deposit. Firstly, the larger inclusions (rocks, pebbles, mortar, etc) were not included in the grain size analysis because only the matrix was sampled. The inclusions measured 6cm or larger. Secondly, although the histogram seems

Figure 6.5: Photograph of the section. Note light layer. Approximate height of the exposed section is 3 metres

to indicate unimodality, this may be misleading. Certainly, the inclusions of rocks and artefacts could constitute another grain size population(s). In the finer grain part of the spectrum, there is a very long and gradual tail, which finally tapers off, with 95 per cent cumulative coarser, at circa $\Phi 22$ (very, very fine clay). All three samples had positive (fine) skewness and were leptokurtic.

The magnetic susceptibility readings were all fairly consistent among the three samples, and did not change much after LOI firing. There was slightly more organic material observed in this section than in the terrace trench (see above), however, the percentage of organic loss was not much higher (2 per cent as opposed to 1 per cent). Phosphate readings were, however, higher, ranging between 2 and 3.

G02: Terrace edge section section

Another section on the terrace edge was cleaned and recorded. This particular section had very clear stratigraphy (see Figure 6.6 and Figure 6.7), and can be correlated with the first terrace section (G01) and the terrace trench (see Chapter 7). The top section seems to have been eroded away, possibly due to the effects of the mechanical irrigation pumps. This section represents the earlier depositional history of this terrace (T4) than G01.

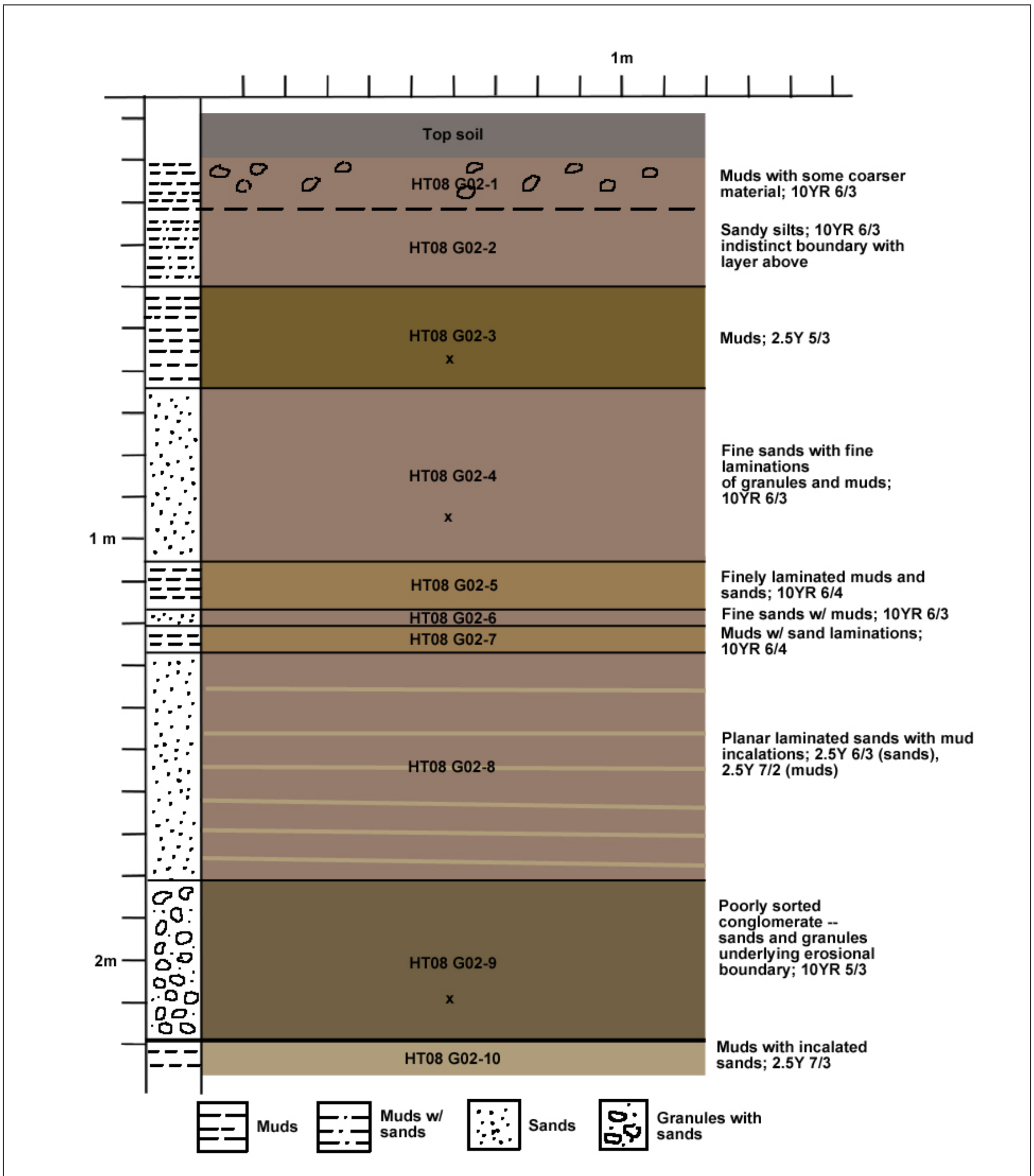

Figure 6.6: Section drawing of the terrace edge section G02. Samples taken are marked with an x, which were later subsampled for phytoliths

Figure 6.7: Photograph of the terrace edge section G02. This section measures approximately 2 metres in height

The bottom of the section is represented by pale yellow muds with intercalated sands (G02-10), overlain by yellowish brown massive sands and granules with intercalated muds (G02-9). There is a sharp, erosional boundary on top of this, suggesting that the river started to incise at this point and alluviation had ceased for an unknown period (see Chapter 7). Alluviation later resumed and is represented by two fining up sequences (G02-8 to G02-5 and G02-4 to G02-1), typical of fluvial sequences.

The first sequence is characterised by light yellowish brown sands with some small layers of light grey muds. The corresponding terrace trench sediments (T01-12 to 8) do not exhibit this switch in hydrology. The next G02 fining up sequence consists of three more layers, two light yellowish brown silt layers, enclosing a pale brown sand layer.

The second sequence starts with pale brown fine sands with granules and mud laminations, overlain by light olive brown muds. Above this sequence are two more layers, consisting of pale brown sandy silts and muds with inclusions, covered with topsoil. The boundary between the sandy silts and muds is not very clear. The corresponding T01 layers (T01-7 to 4) do show a similar decrease in hydrological power.

Three samples (G02-3, -4 and -9) were further analysed to provide additional information regarding depositional history and to help correlate with the other two sections. The mean grain sizes of all three samples are consistent with medium silt and are poorly sorted. The mean grain size is somewhat surprising for Samples G02-3 and G02-9, which in the field were described as sands. However, as seen with samples from the terrace trench and other gully section, these sediments are very mixed, and the sandy layers contain a lot of silt. This is further supported by the long tails that these samples exhibit as well as their positive skewness. These samples are also very leptokurtic.

The magnetic susceptibility readings were fairly similar across the three samples and all had slightly lower readings once the samples had been fired. The organic loss percentages, as with the other samples, were also low, at 1 to 2 per cent. The phosphate readings were also generally low, although G02-4 had a slightly higher reading of 2.

6.2.2 Phytoliths

Phytolith samples were taken from offsite and onsite contexts, and will be discussed separately. Offsite samples were taken from the small trench and two terrace edge sections of the main terrace below the tell. The temporal range is ?EBA through the MBA (layer sealed by the IA or Byzantine flood layer). The onsite samples all come from the tell site itself (no samples were retrieved from the lower and outer towns, which were excavated prior to my inclusion on the project). The dating is further discussed in Chapter 7. The raw data for phytolith counts can be found in Appendix G. Histograms and line graphs not shown in this chapter can be found in Appendix H.

Offsite samples

The samples taken for analysis are marked on the section drawings. The samples were taken from the contexts discussed above in the Geoarchaeology section, and have the same sample numbers. Dating of these samples is based on the chronology of the geoarchaeological samples. In the histograms, the samples are listed in chronological order, with the oldest samples first.

Some of the phytoliths will likely have been transported from elsewhere as this is an alluvial landscape; other phytoliths, however, will have been deposited *in situ* (possible parameters for determining depositional mechanisms are discussed in Chapter 5). As such, it is hoped that both local and regional signals for vegetation change and land use may be detected.

Taphonomy and phytolith abundance

Offsite samples have relatively fewer phytoliths per gram than on site samples. As discussed in Chapter 5, more sediment is needed in the processing stage in order to increase the number of phytoliths present. This does not necessarily increase the silica percentage or phytolith abundance per gram, however, it increases the chance of reaching counts that will be more robust for statistical analysis.

The phytolith abundance (see Appendix H) in most of the samples is very low (less than 15,000/gram), however, two samples, G01-4c and G01-4a, stand out with counts of over 400,000/gram, which is comparable with onsite samples. Minimum counts were not reached for all samples. The total silica count (see Appendix H) is also low in most samples, ranging from about 0.5 to 0.9 per cent.

However, two samples, G01-4c and G01-4a, have higher percentages (5.2 and 4 per cent respectively), which compares with the onsite samples. The percentages are generally higher here than those from the Shahrizor plain (see below).

Preservation of phytoliths was variable across the samples. Some phytoliths were 'weathered' or dissolved, while others were fragmented, making identification difficult. Many could have been transported from elsewhere. Other phytoliths, particularly the large multicells from T01-6, were well preserved and showed little dissolution.

Single cells dominate over multicells in all samples as expected, however the proportions do vary somewhat with proportionally more multicells in samples T01-6, T01-5, G02-4 and T01-4 (see Appendix H).

Other silica microfossils and charcoal

Other silica microfossils include diatoms, sponge spicules and possible fern phytoliths and were found in several of the samples, T01-7a, T01-4 and especially G01-4a (ses Appendix H). Charcoal was also found in some of the samples. No burnt and/or melted/warped phytoliths were seen.

General trends

The comparative percentages between single cell rondels, bilobes and saddles indicate that for the most part, pooid grasses (i.e., rondels) dominate the record, which in turn indicates a continuing temperate climatic regime. There is one anomaly, however, and that is sample T01-5, where there are no rondels present (see Appendix H). However, it is unlikely that this is some sort of sudden climatic and or vegetation shift at this point. It should be noted that there were very few phytoliths in this sample, so counts were not reached and only three bilobes and seven saddles were identified. Cereal straw (multicells) was also identified, thus cereals are present in this sample.

Wetland plants, grasses (including cereals) and dicots are all present (see Figure 6.8). Where counts are higher, it can be seen that monocotyledons outnumber the dicotyledons (see Appendix H). Percentages indicate that dicotyledons are at about 10 to 30 per cent of the total (see Appendix H). Dicotyledon phytoliths include fruit, bark and wood, and leaf material (see Figure 6.9). The numbers peak in samples G01-4c and G01-4a.

Jigsaws are present in several samples, in low numbers (T01-7a, T01-4a) and in much higher numbers in two of the samples (G01-4c and G01-4c). And G01-4a even contains some multicell jigsaws (see Appendix H).

There are also variations in the ratios of grasses to wetland plants (see Appendix H), and in the oldest layer, no grass phytoliths were detected (see Figure 6.8). Possible and definite cultivated/domesticated species were also indicated in some of the samples. T01-6 contained emmer wheat multicells, other samples contained cereals and agricultural weeds as well as possible fruit phytoliths (see Appendix G and Chapters 7 and 8 for further discussion).

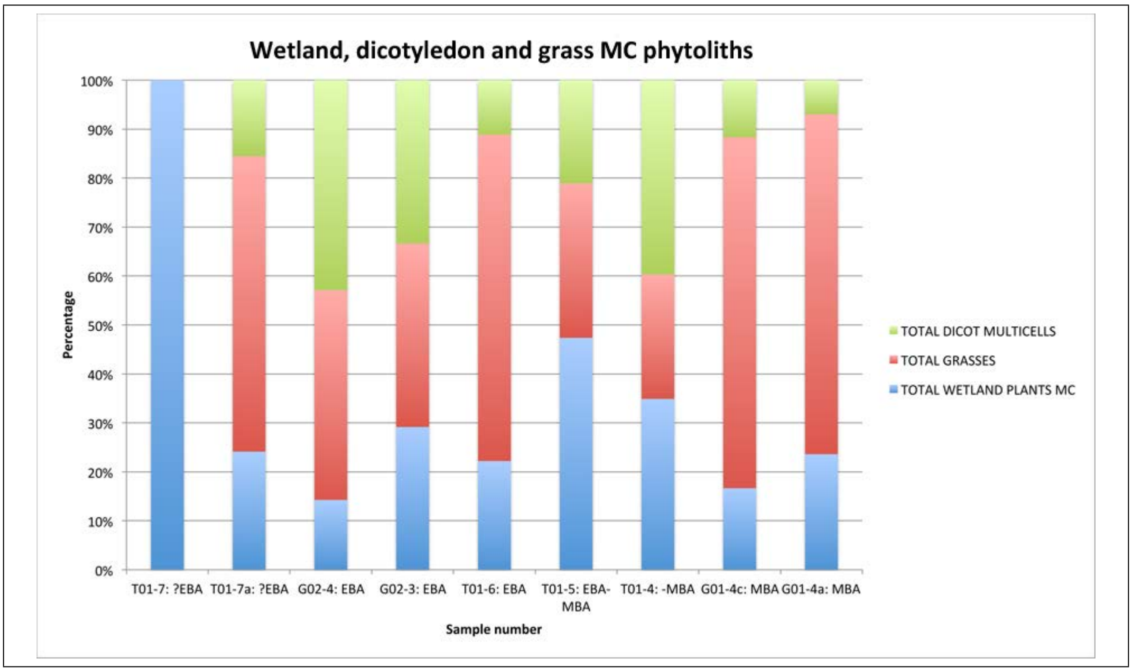

Figure 6.8: Histogram showing the relative percentages of wetland, dicotyledon and grass multicell phytoliths

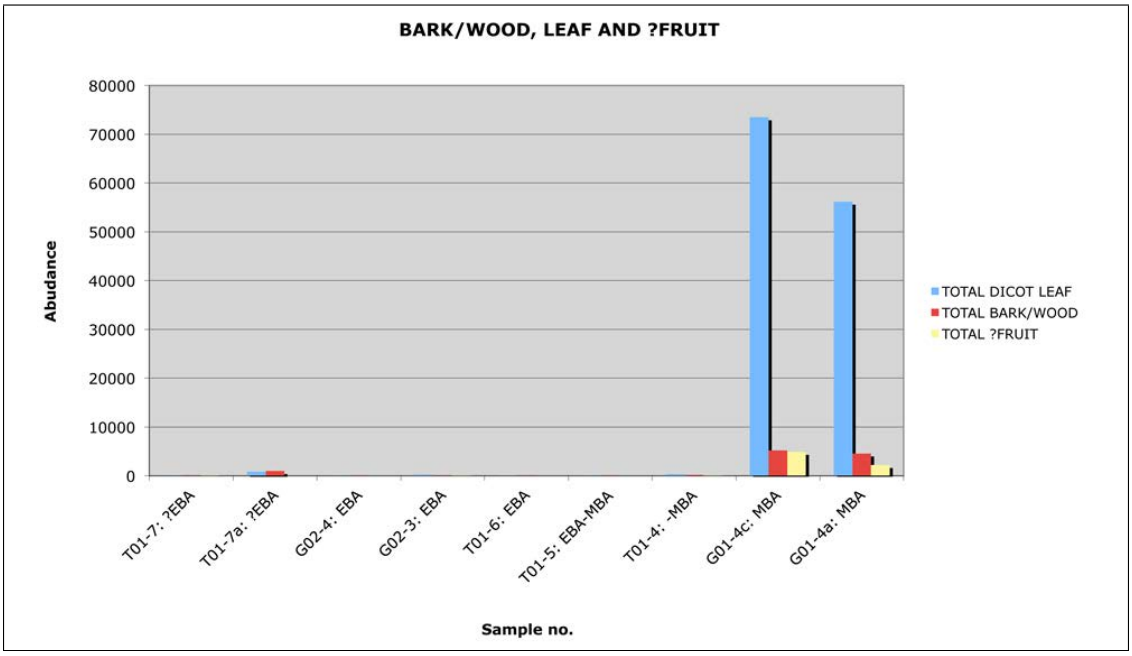

Figure 6.9: Histogram showing the abundance of different dicotyledon phytoliths

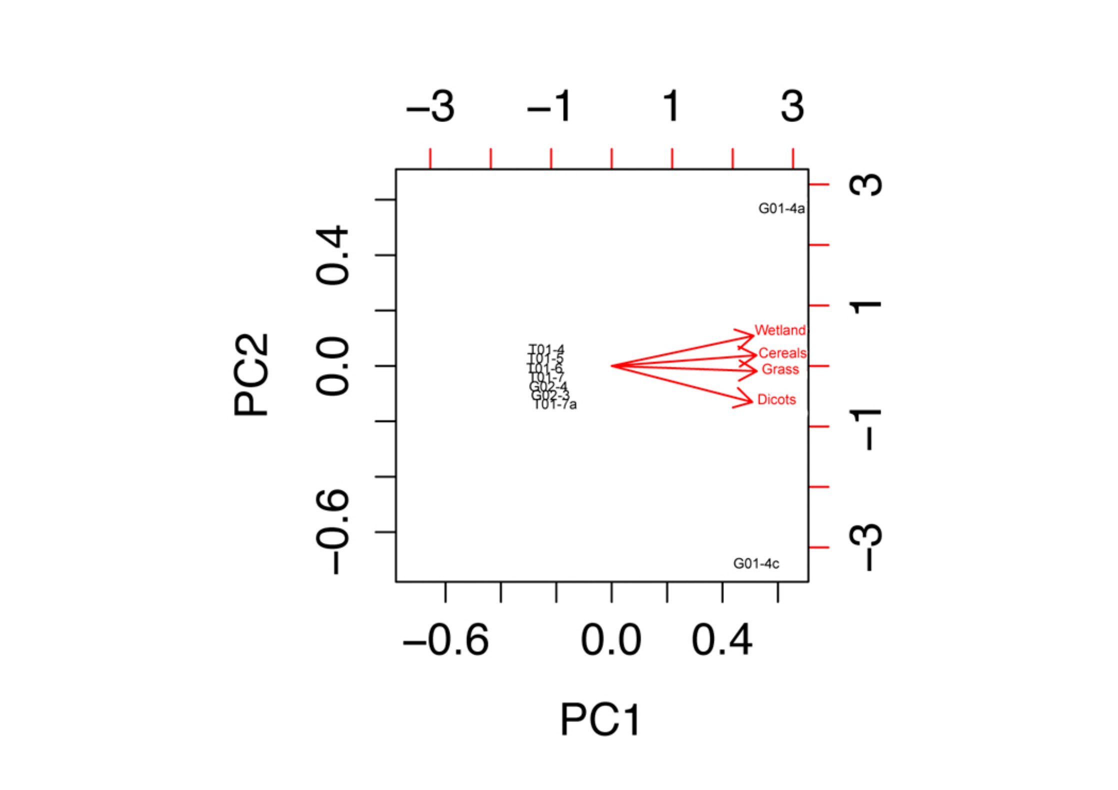

Figure 6.10: Biplot of PC1 and PC2 values of samples. Arrows indicate correlation of variables (dicotyledons, wild grasses, cereals and wetland plants). All samples included. NB: samples T01-4...T01-7a were clustered on top of each other; they have been adjusted to aid in legibility.

The phytolith data was further interrogated using multivariate analysis, specifically principal component analysis (PCA), to see if there was any relationship between cereals, wild grasses, wetland plants and dicotyledons. Multicells counts were used for this analysis. As can be seen in Figure 6.10, the samples cluster together, showing similar variation. PC1 accounted for 97 per cent of the variation, with all variables having similar positive correlation with PC1 (ranging from 0.49-0.50). PC2 accounted for very little variation, with wetland plants having a high positive correlation (0.62) and dicotyledons having a high negative correlation (-0.74). The different variables are weakly correlated with each other, as indicated by the arrows. There are two outliers, samples G01-4a (top right) and G01-4c (bottom right), which could be the result of the number of phytoliths in these two samples (the counts were much higher than in the other samples as mentioned above). When these two samples are removed (see Figure 6.11), the correlation between dicotyledons and wild grasses is strong, however, there is a weak correlation between dicotyledons and wetland plants, and cereals are now completely uncorrelated. PC1 accounts for 62 per cent of the variation (with wetland plants (0.51), wild grasses (0.62) and dicotyledons (0.57) being strongly positively correlated with PC1) and PC2 accounts for 24 per cent of the variation, with cereals being very strongly correlated (0.95). There also appears to be more variation between the rest of the samples, although two still cluster (G02-4 and T01-7). Two samples stand out: T01-6 and T01-7a. This indicates that there are some fluctuations in the vegetation over time, particularly with T01-6 and T01-7a.

Indices

Four indices were calculated on these samples: tree cover index (D/P ratio), aridity index (Iph), climatic index (Ic) and water stress (Fs). The results are listed in Table 6.1. It should be borne in mind, however, that the number of phytoliths in the samples is small in some cases, making these results not particularly robust (see Chapter 5). However, the results do give some tantalising, if tentative, support to the other evidence presented.

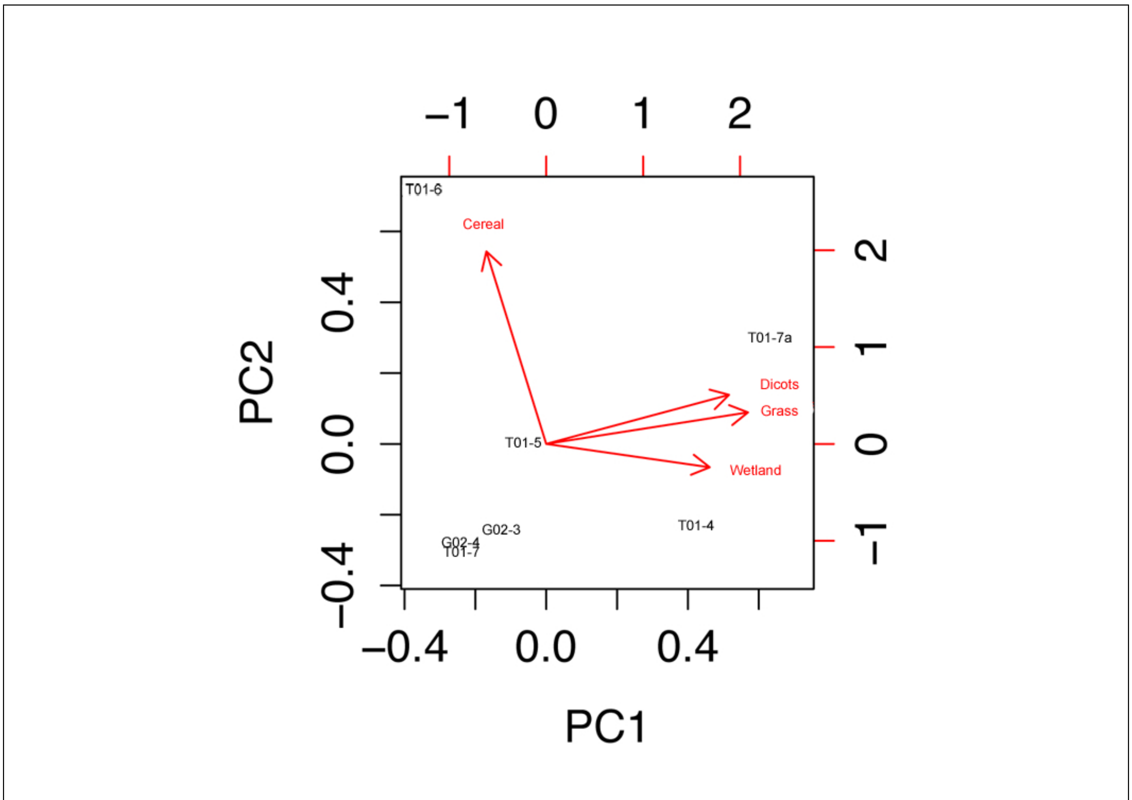

Figure 6.11: Biplot of PC1 and PC2 values showing variation between samples, after samples G01-4a and G01-4c have been removed. Arrows indicate correlation of variables (dicotyledons, wild grasses, cereals and wetland plants). NB: G02-4 and T01-7 were clustered on top of each other and have been slightly adjusted to improve legibility.

Generally speaking, the D/P ratios vary across the samples (T01-7a is quite high in comparison with the other samples) and indicate fluctuating levels of tree cover (using values for the Mediterranean area from Delhon *et al.* 2003). The aridity index seems to indicate (in the limited values that were calculable) that there were drier conditions over time. The climatic index (C_3 versus C_4 plants) indicates, on the other hand, that temperate conditions may have prevailed, with a fluctuation in sample T01-5 (but see discussion above). The water stress (Fs) values measure water availability: the higher the values, the less water there is (Barboni *et al.* 2007). The water availability varies across the samples and may reflect changing hydrologies (flood farming) as well as channel irrigation. T01-6, G01-4c and G01-4c have particularly low values and thus higher water availability.

In one sample (T01-6), there were multicells consisting of 100+ conjoined cells, also indicating higher water availability.

Onsite samples

The samples presented here come from a variety of contexts, including floors, tannours, hearths, destruction layers and groundstones. The temporal range is from the late EBA into the LBA. The evidence will address issues regarding site economies and resource use. Some environmental signals (background noise) may also become evident, adding to the environmental information provided by the offsite phytolith samples and geoarchaeological investigations.

Site: HT terrace samples									
Sample	T01-7	T01-7a	G02-4	G02-3	T01-6	T01-5	T01-4	G01-4c	G01-4a
D/P ratio	0.142857143	0.304347826	0.071428571	0.034883721	0	0.15	0.15645815	0	0.029411765
Iph	divide by zero error	0	divide by zero error	0	divide by zero error	0.7	0	0.75	0.75
Ic	1	0.971428571	1	0.950819672	1	0.642857143	0.842105263	0.93442623	0.960784314
Fs	0.238095238	0.263157895	0.375	0.150537634	0.0625	0.666666667	0.327868852	0.021126761	0.034883721
Irrigation/ high water avail (10+ MC)	no data	no data	no data	no data	no data	no data	no data	no data	no data
100+ MC	no data	no data	no data	no data	5	no data	no data	no data	no data

Table 6.1: Figures for the four indices as well as large multicell counts

Taphonomy and phytolith abundance

Total silica content (including phytoliths, diatoms, ferns and sponge spicules) mainly hovers around 10 per cent or less, with two prominent exceptions, SC99-1 (ashy deposit) and SC147-1 (a tannour deposit), which are both over 20 per cent (see Appendix H).

Phytolith abundance is much higher than that of the offsite deposits (see Appendix H). Most of the samples ranged between 250,000 to 600,000 phytoliths per gram of sediment, but there were a few with more than this: three samples had values over 1,000,000 (S01-8, SC517-1, SC551-1), one had over 3,000,000 (SC624-3), and SC99-1 had well over 8,000,000. SC99-1, an 'ashy deposit', had a high silica content as well as a high phytolith abundance. SC147-1, on the other hand, a tannour deposit, had a fairly high silica content but a relatively low phytolith abundance. SC624-3 (another tannour) had a low silica count in comparison, but a much higher phytolith abundance.

Although multicells were found in all contexts, they are normally outnumbered by single cells, as is expected (see Appendix H). Four deposits (SC99-1, SC518-2, SC160-6 and SC624-1) have more than 30 per cent multicells (of total phytoliths), and indeed SC518-2 was very high at 55 per cent. All of these samples are from contexts which are both ashy/burn or tannour deposits.

In some of the tannour samples, however, there are very few multicells, perhaps more to do with the contents of the fill (i.e., fuel type) rather than preservation (more on this below). In other contexts, such as floors and possible door sockets, there are also comparatively few multicells. As discussed in Chapter 5, the abundance of multicells is expected to be less than single cells in onsite contexts, not only because of general taphonomical issues and sampling damage, but also because many of the multicells, particularly those of cereal husks, may be mechanically separated during grain processing activities.

Other silica microfossils and charcoal

Although phytoliths made up the majority of the silica content, diatoms were present in most of the samples, but in low numbers (see Appendix H). In one sample, SC147-2 (tannour fill), diatoms made up almost 15 per cent of the silica.

There is no correlation between the wetland plants and the diatoms (0.33; see Table 6.2), meaning that the diatoms did not come in with the wetland plants. Possible ferns were also present in two samples (SC517-1 and SC569-1) and sponge spicules in three samples (SC624-2, SC625-1 and SC569-1).

Charcoal was noted in about half of the samples, and some of the samples also contained burnt phytoliths (including SC624-3, SC106/2264, SC147-1 and SC147-2; see Figure 6.12).

General trends

The histograms are organised temporally, with the earliest contexts (EBA) starting on the left and progressing through the MBA and LBA. Some contexts have calibrated C14 dates. Unfortunately, there are only two samples from the late EBA and none from earlier contexts, because in most areas the EBA was not reached (and never will be as the site has now been covered up).

Temporally speaking, there do not seem to be able discernible changes, rather changes seem to reflect contexts. Dicotyledons are present throughout, and range from 5 to 15 per cent of the phytolith counts. Any variation probably reflects usage on the site, rather than environmental change. Wetland plants, consisting mainly of sedges, although there are a few examples of phragmites as well, are found throughout, and again seem to be dependent more on context rather than temporal trends.

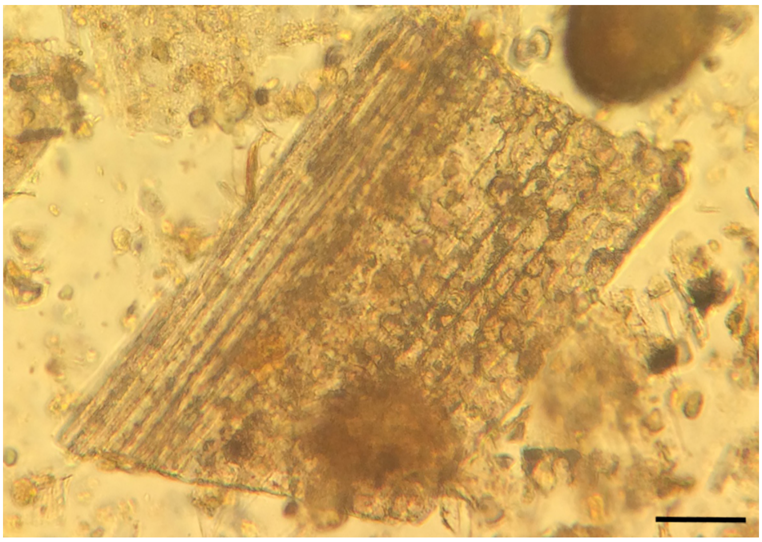

Figure 6.12: Possible burnt sedge multicell phytolith. Measurement bar is 10 micrometres

Pooids (C_3 rondels mainly), of course, dominate the record (see Appendix H), and there do not seem to be any temporal trends in terms of wheat numbers against barley (although in many cases, it was not possible to identify the multicells to this level: see Figure 6.13). Furthermore, the barley phytoliths may actually be from the wild variety rather than the domesticated crop (see Chapter 7).

The EBA samples come from the same area. SC08 was dated to cal BC2349-2138 (2 sigma) and SC19-1, which underlies SC08. There were not many phytoliths, perhaps because these are floor layers and would therefore have been swept up. There are dicotyledons, wetland plants and cereals all present although in low numbers (see Figure 6.14).

More samples were obtained and analysed for the MBA and LBA, and there are some variations in dicotyledon (see Figure 6.14), wild grasses and cereals (see Figure 6.16) and wetland plants (see Figure 6.15) in these samples. Monocotyledons, as is expected, dominate the record in all of the samples over dicotyledons (see Appendix H). Dicotyledon percentages range from about 5-18 per cent (using the unadjusted figures). Most of the tannour fills contain the higher percentages of dicotyledons, perhaps indicating wood as a fuel. However, only two tannours contained wood/bark phytoliths. Dicotyledons may also be represented by building material (bark, wood) and even fruit: possible fruit polyhedrals were found in two samples (SC624-2 tannour, S01-8 fill layer and SC99-1 ashy deposit: see Chapter 7). There were also many phytoliths deriving from leaves of dicotyledons.

Wetland plants, as mentioned above, are ubiquitous throughout, but are particularly abundant in two of the samples (SC99-1 and SC160-1). They are mainly represented by sedges, with few reeds/phragmites.

Grasses, unsurprisingly, make up the majority of the phytoliths, and are represented by wheat, barley and wild grass/agricultural weeds. Cereal husks were found in some but not all of the samples. In most cases, it was not possible to identify them as either wheat or barley, making it difficult to discern patterns or trends. As both wheat and barley were found in the offsite samples, it is likely that both were used onsite during the MBA. There is some covariance between wild grass and cereal husks, although this is not universal. There is also a positive correlation (0.94) between wild grass and cereals, indicating that many of the wild grasses came in together with the cereals as weeds. However, when barley only is compared with wild grasses, there is no correlation. It is thus unlikely that the barley is a weed (see Ryan 2009).

Phytoliths correlated	**Results**
BARLEY/WHEAT CORRELATION ALL	-0.023051368
BARLEY/WILD GRASS CORRELATION ALL	-0.075546409
Barley/wheat correlation (exc piazza)	0.074420157
Barley/wild correlation (exc piazza)	0.753505741
Wheat/wild correlation (exc piazza)	-0.019283978
Cereal/wild correlation (exc piazza)	0.526735589
Barley/wheat correlation (Piazza)	0.735671775
Barley/wild correlation (piazza)	-0.328563841
Wheat/wild correlation (piazza)	-0.30580006
Cereal/wild correlation (piazza)	0.390908124
Barley/wheat correlation EBA	1
Barley/wild correlation EBA	-1
Wheat/wild grass correlation EBA	-1
Cereal/wild grass correlation EBA	-1
Wheat/wild grass husks correlation ALL	0.98512074
Cereal/wild grass husk correlation ALL	0.941697197
diatom/wetland plant correlation	0.3300369

Table 6.2: Table of correlation results discussed in this section and in Chapter 7

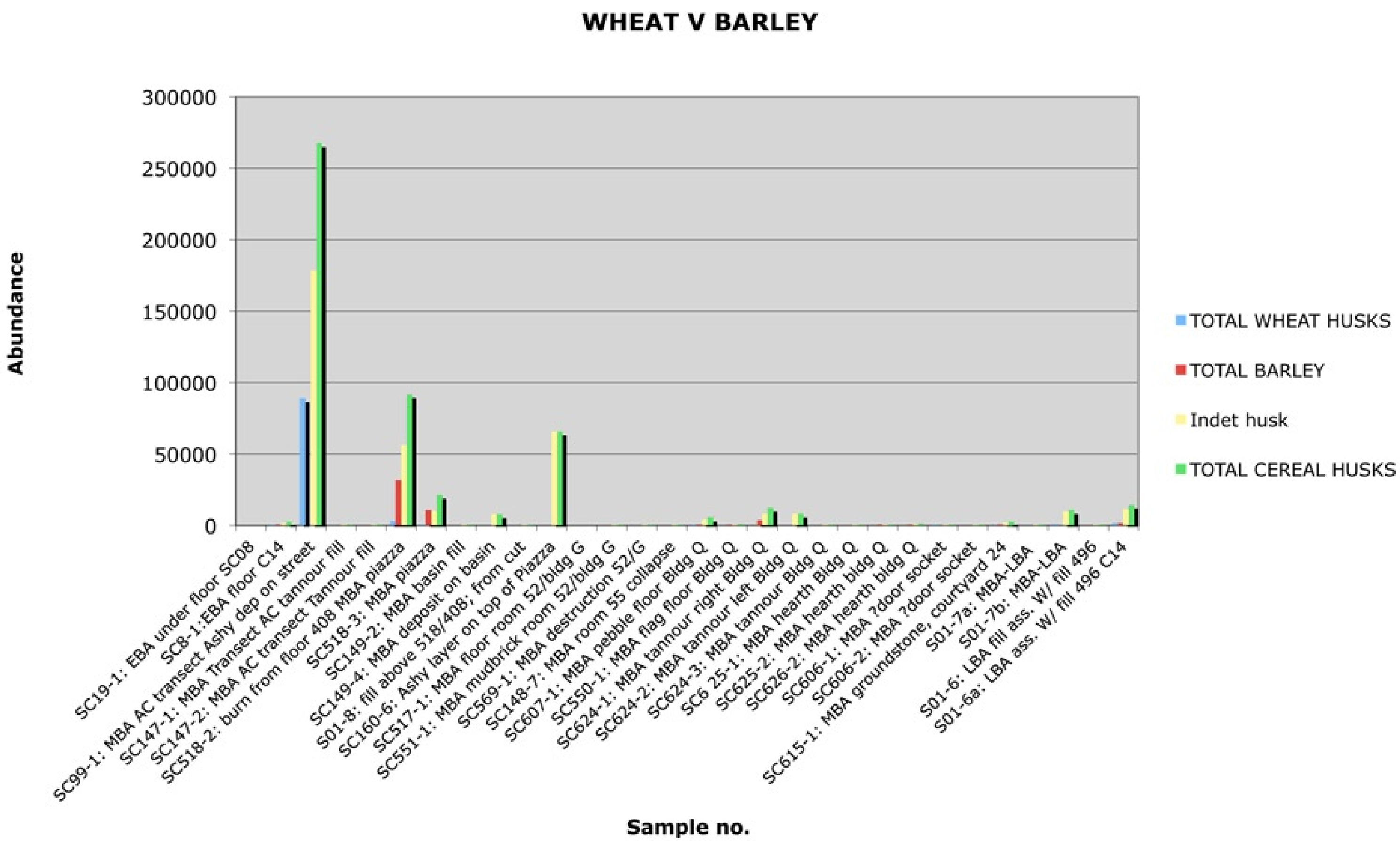

Figure 6.13: Wheat and barley abundance

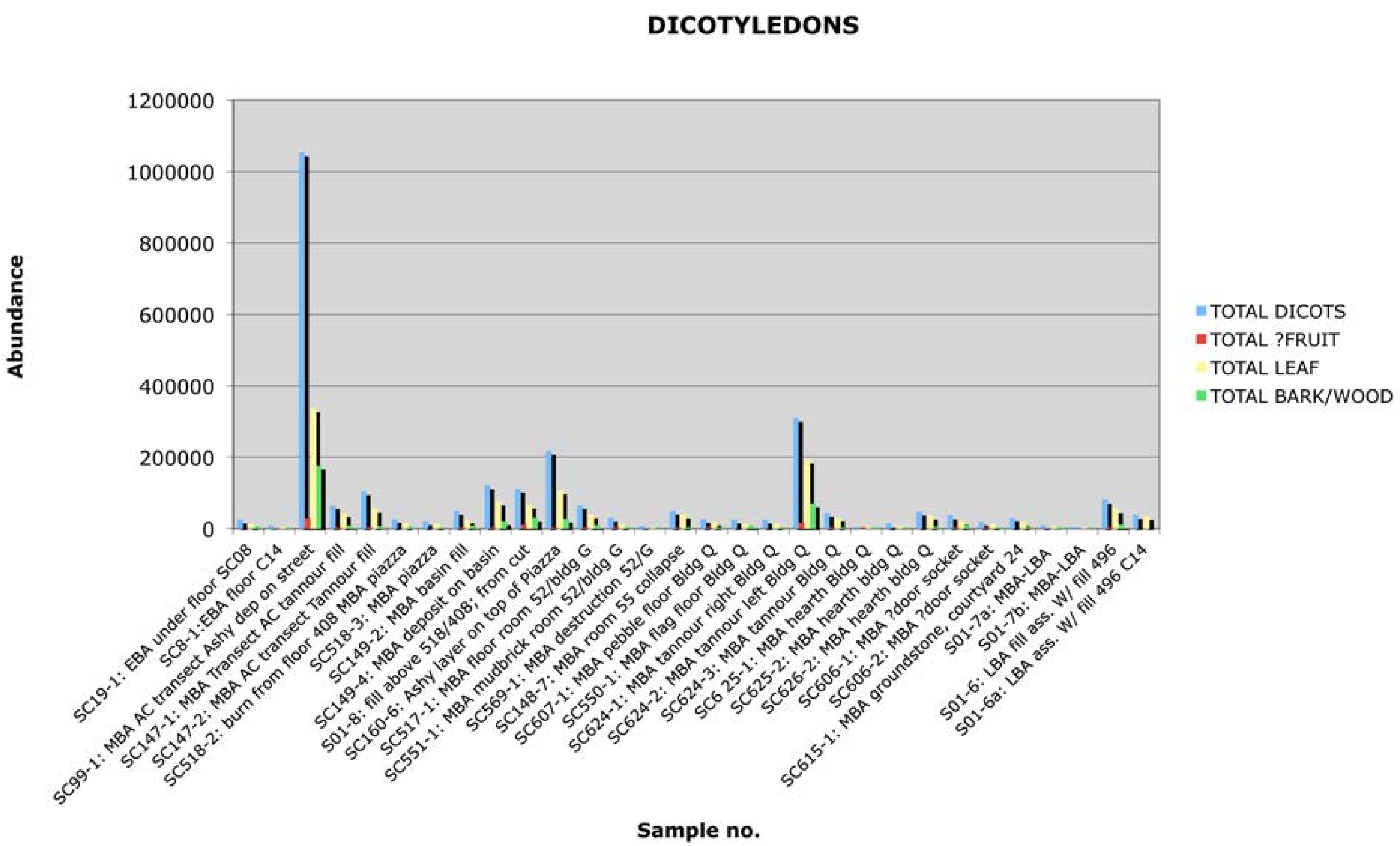

Figure 6.14: Abundance of different types of dicotyledon phytoliths

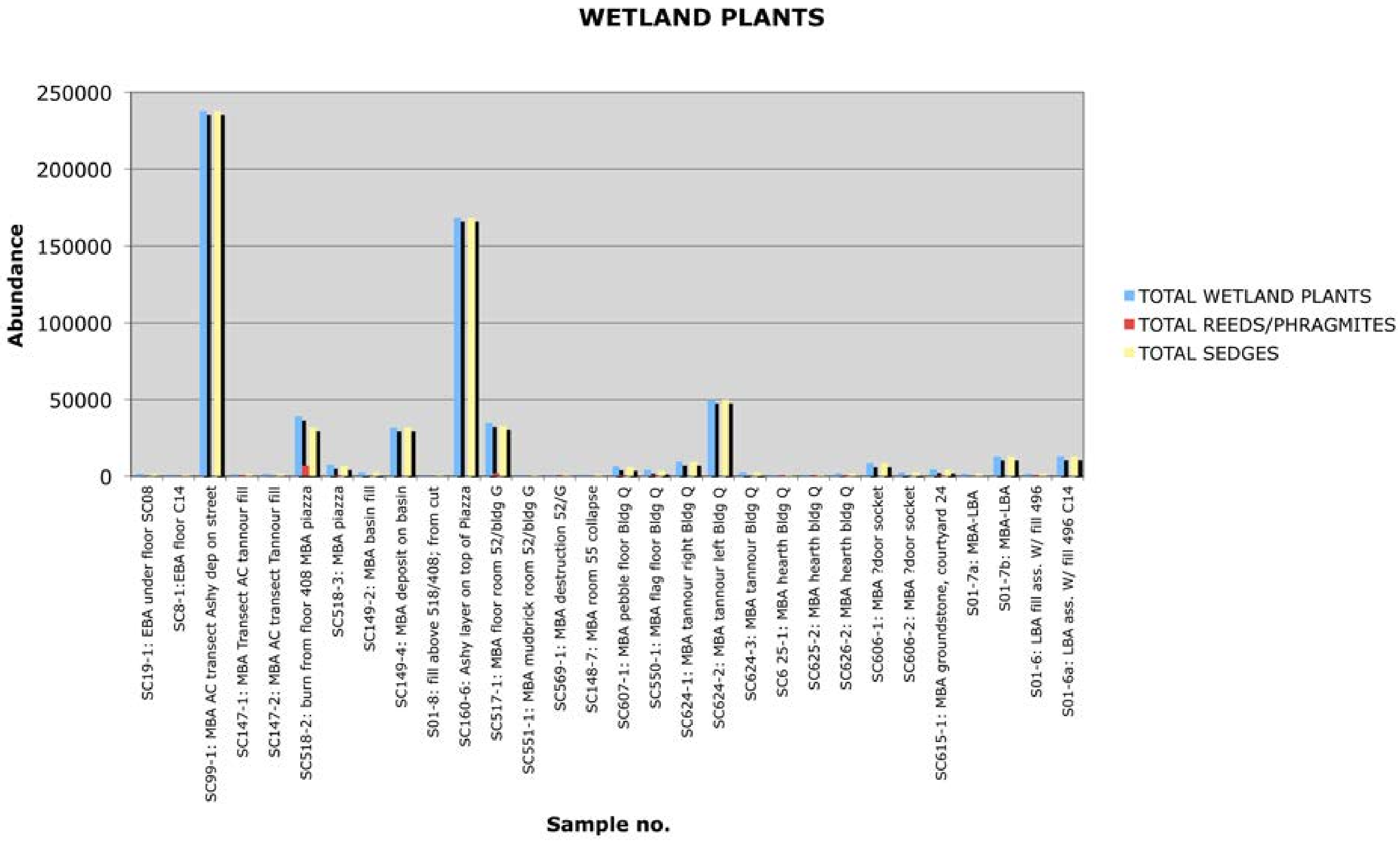

Figure 6.15: Abundance of wetland plant phytoliths

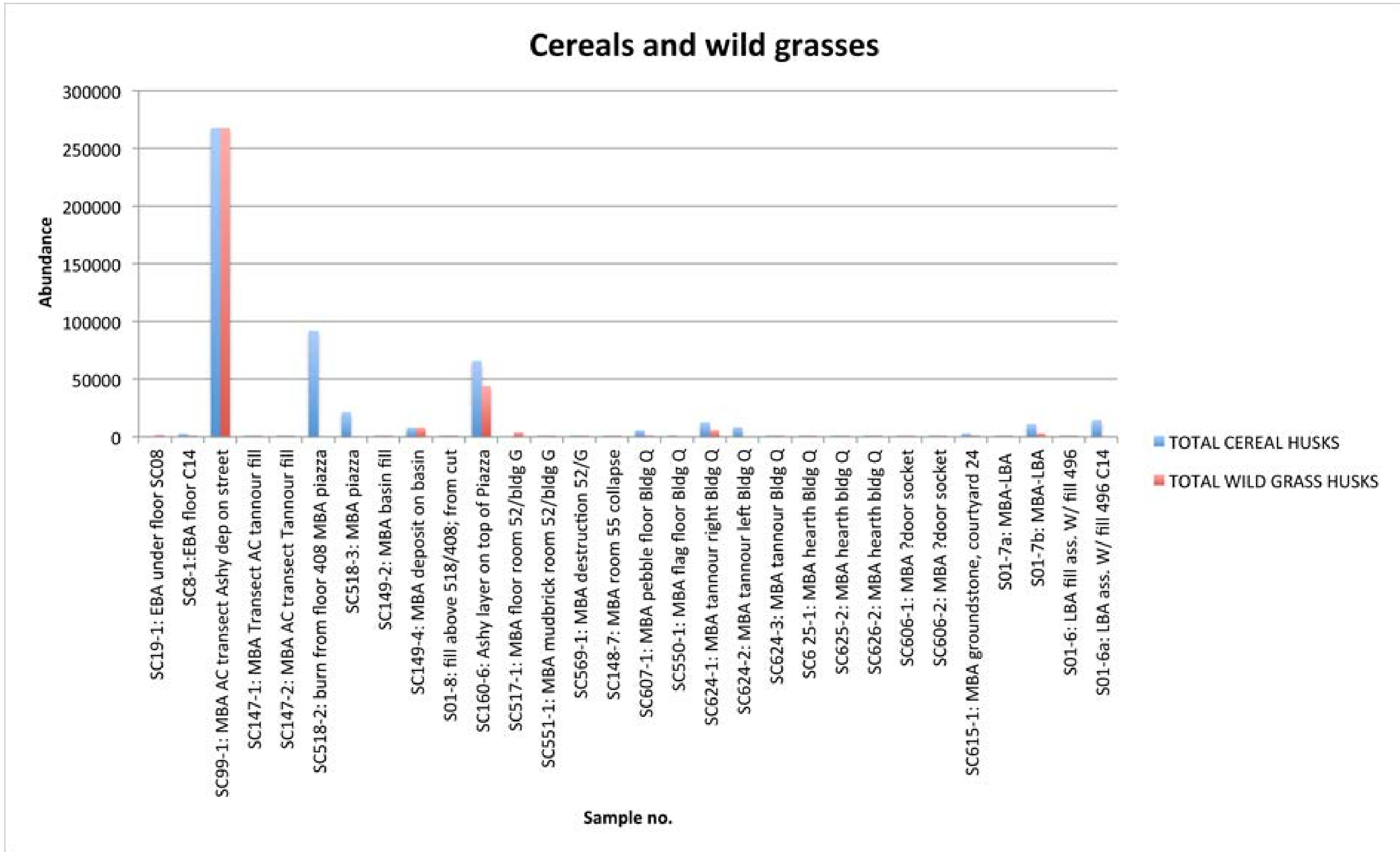

Figure 6.16: Abundance of wild grass and cereal phytoliths

6.3 Shahrizor plain and Bakr Awa

6.3.1 Geoarchaeology

Introduction

Very little palaeoenvironmental work has been done in Iraqi Kurdistan. There have been some studies of the structural geology by the department of Geology at University of Suleimaniya (see, for instance: Karim *et al.* 2008), but most of this concentrates on much earlier geological periods and tectonics. The only work on the Quaternary is a PhD thesis on modern hydrology in the karstic region (Ali 2007); there have been no studies (at least published) on the Quaternary sediments in the plain itself, and few on modern soils (the main source is Sehgal 1976). There was some palaeoenvironmental work carried out in the 1960s by H E Wright and H Helbaek for the Jarmo excavations (Braidwood and Howe 1960). This work is now being continued by Professor Dorian Fuller (UCL) at Jarmo. There have also been palaeoenvironmental studies carried out on several lakes including Lakes Zeribar and Maribar in Kurdish Iran, and Lake Van in Turkey. Analysis of pollen, diatoms, sediments and other proxies have been carried out at these sites since the 1950s (see Chapter 2).

Unlike the survey of the environs of Hirbemerdon Tepe, which encompassed the immediate area around the site, the geaoarchaeological survey of the Shahrizor extends from Suleimaniya in the north of the plain to Halabja in the south. It is part of a larger project which includes a historical geographical survey project (directed by Professor Karen Radner of UCL), a site survey project (directed by Dr Simone Mühl of University of Munich), a palaeoecological survey (directed by Dr Mark Altaweel of the Institute of Archaeology, UCL) and several site excavations, including Bakr Awa (directed by Dr Peter Miglus of Heidlberg University). There have been several seasons of geoarchaeological survey, including the survey of the plain (undertaken by Dr Altaweel and myself in 2011, 2013 and 2014) and two seasons of coring (undertaken by Dr Rob Homsher and Professor Arlene Rosen with Dr Altaweel). The results presented here are based on the 2011 to 2014 surveys, and will concentrate mainly on the sedimentology of the large trench excavated near Bakr Awa, with reference to trenches excavated in Bagum and Yasin Tepe (see Figure 3.24) and general remarks on cores extracted between Bakr Awa and Gurga Chiya. The results here are preliminary, and sediments have not been analysed in the laboratory as yet; the analysis will start late 2014.

Survey

Desk-based research was based primarily on the reports and dissertations by staff and students at the University of Suleimaniya, and most of the studies focused on the hard rock geology as well as the tectonic activity in the region, as well as the PhD thesis on the hydrology and karstic features (Ali 2007). Digital Elevation Modelling (DEM) data and satellite (Quickbird) imagery was obtained by Dr Altaweel, and topographical maps (again by the Russian military) were downloaded. The geology and topography is described in more detail in Chapter 3, and has been published elsewhere (see Altaweel *et al.* 2012, Marsh and Altaweel In press), and so is only briefly recapped here.

The plain itself lies between the foothills of the Zagros mountains and the Binzird, Baranan and Qara Dags on the west (which divides this region from Kirkuk and the Chememal area) and is part of the Zagros thrust zone on the border of the Arabian plate (Beaumont *et al.* 1976, Altaweel *et al.* 2012). The surrounding uplands consist mostly of limestone of the Cretaceous period, and contributes to the sediments deposited in the plain. There are two dominant types of limestone, as seen in the gravels of the Pleistocene terraces: a bluish limestone and a pinkish limestone. There are also many limestone caves in the uplands, and speleothem investigations have commenced in the region.

The valley is dissected by the major river, the Tanjero, which runs north to south and flows into the Darban-i Khan dam lake, which was created in the 1960s. The Sirwan (Upper Diyala) has its origins from the area that is now submerged under this lake and the confluence of the Tanjero and Sirwan are here (Altaweel *et al.* 2012). There are many tributaries, mainly now wadis, that flow into the Tanjero and the dam lake from the hillsides on both sides (see Figure 3.24), and these as well as the Tanjero are the major transportation mechanisms of sediment from the hills into the valley. Other transport mechanisms include gravity movement (colluvial sediments closer to the slopes of the uplands) and wind. The sediments range in size, mainly from gravels to clays, and are mostly reworked terra rosa soils from the hills (more on this below).

The plain is undulating, due to the number of terraces and incisions which have formed by the Tanjero and its many tributaries, and colluvial deposits at the bases of the slopes.

Sections and trenches

In order to better understand the environmental changes within the Iraqi Kurdish area, and how these might relate to the evidence found in surrounding Kurdish regions (Turkey and Iran), the Shahrizor project was initiated. The first season was primarily a pilot study, and an opportunity to tour the intermontane plain area between Suleimaniyah and Halabja, record and in some cases, sample features. This was followed by several seasons of coring and further trenching, stretching across the Shahrizor plain from Bakr Awa in the south to Yasin Tepe in the north.

The 'deep trench': Bakr Awa trench

The deep trench was excavated with a mechanical digger and measured 44 x 4 x 6m in total (22 m length was drawn). The depth ranged from about 1 meter to 6 meters at the far end. An additional one meter square sounding was dug at the 6 meter level to reach 7 meters depth. The two long sides of the trench (OST1 East and West) were drawn, photographed and sampled (see Figure 5.4 for an image of the trench). The far (northern) section was not clean enough for detailed and accurate recording, however it too was quickly sketched and photographed. Because of the height of the lowest part of the trench and because a ladder could not be safely placed, it was not possible to sample the entire section in one area. Instead, sampling was staggered along the sides in order to cover the temporal range of the sediments.

At the base of the trench, around 6 metres down, a gravel layer was reached. This gravel layer differed from the other gravel layers above in several respects. Firstly, the colour of the gravel differed – it was more pinky rather than the blue of the gravels above, suggesting a different Cretaceous limestone source material (the gravel consisted of mainly limestone). Secondly, there was an abrupt boundary between this gravel and the silty clay layer above, and thirdly, there is a colour change (to brown). This suggests that the boundary is an erosional one and may mark the end of the Pleistocene sequence. This in turn suggests that the succeeding sedimentation is all Holocene.

A sherd of pottery was found at *circa* 5 metres down, helping to confirm the Holocene age of the deposits. One diagnostic sherd (Achamaenid) was found above the first wadi cut in the western side of the deep sounding, about 1.5-2 metres down. Thus the sediments between *circa* 2 metres to 6 metres (where the gravel sits below an unconformable boundary) most likely represent Holocene sedimentation from *circa* 2500 to 12,000 BP.

As mentioned before, two sides of the trench were recorded and sampled. Although they are broadly similar, they will both be described as there are some differences which could reflect microenvironments. Descriptions can be found in the section drawings.

The east side (OST1 East, see Figure 6.17)

The bottom of the trench was marked by a gravel base (probable Pleistocene gravels) at about 6 metres depth. This was overlain by a dark reddish brown (5YR 4/4) clay layer, OST1-1. Sediment and phytolith samples were taken. This layer contained iron flecks/nodules, which were flat, and few calcium nodules (or concretions). Above this, at about 5 metres, was a layer (OST1-2) which contained more silts (it was grainier to the touch), but was still very clay rich. There was a slight colour change to brown (7.5YR 4/4) and the boundary with OST1-1 was difficult discern. This layer also contained far more calcium nodules. There was a channel cut just above this layer, at circa 3.5 to 4 metres depth, likely eroding the top of this layer. This can be seen in the section drawing; OST1-2 continues up to about 2 metres, where there is yet another channel cut.

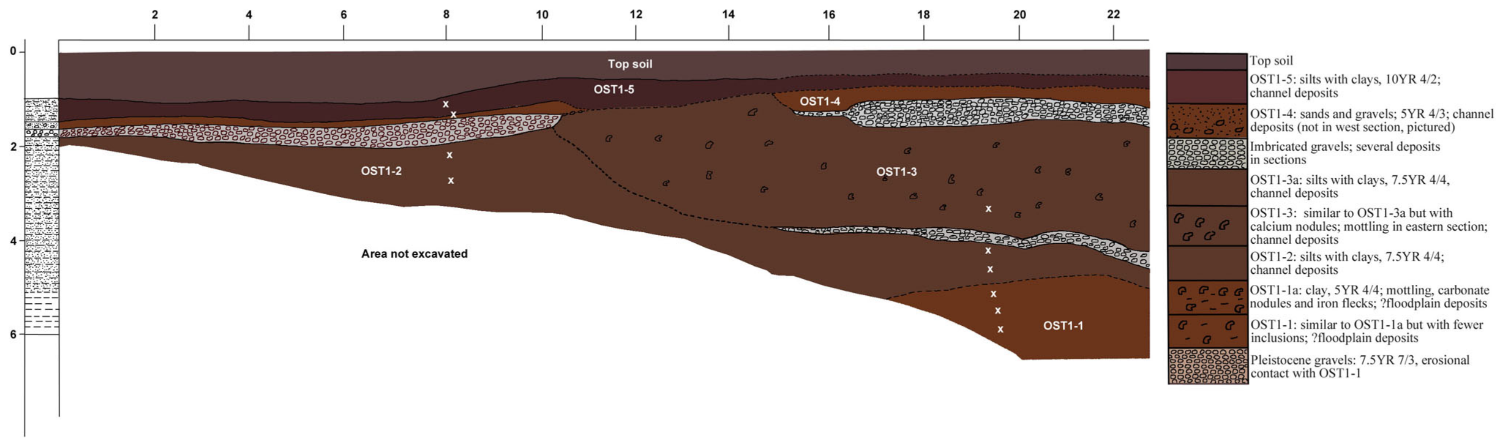

Figure 6.17: Section drawing of the eastern side of the deep trench, including lithology and sediment descriptions. Phytolith samples are marked with an x

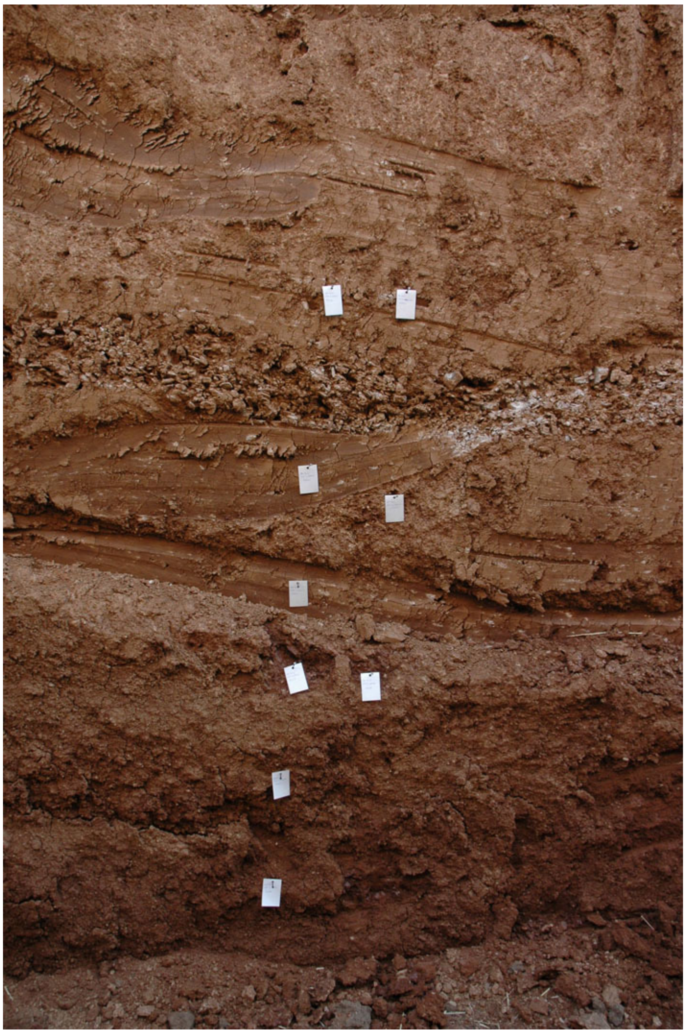

Figure 6.18: Photograph of part of the eastern section. It was not possible to photograph the entire section. The photograph shows the deepest part of the trench, about 20 meters across. The tags on the left indicate phytolith samples, the ones on the right are sediment samples taken for later laboratory analysis

Above the first channel cut (3.75 metres) is another layer, OST1-3, parts of it which are mottled (red and grey) towards the top and contains calcium nodules, although not as many as OST1-3 on the west side. The mottled area may be related to OST1-3a (see below), but there is no boundary visible at all on this side. The colour is again brown (7.5YR 4/4). Above the second channel cut at 2 metres, there appears to be a fining up sequence consisting of gravels and sands (OST1-4) overlain by silty clays (OST1-5). Both are reddish brown (5YR 4/3). OST1-5 is overlain by the modern top soil and its associated horizons.

The west side (OST1 West, see Figure 6.19)

At the bottom of this section, the same gravel layer was encountered. A test pit was dug to 7 metres and the gravels continued to this depth. The matrix was pink (7.5YR 7/3). The layer immediately above was the same as on the east side (OST1-1), clayey sediment reddish brown in colour and containing many iron flecks but few calcium nodules. There was a small area of mottling (OST1-1a), several metres wide, not matched on the east side, suggesting a slightly different microenvironment.

OST1-2 was similar to its counterpart on the east side. The channel cut in OST1-2 East at 3.75 to 4 metres was barely evident on the west side (smallish gravel lens), suggesting that the channel angled away, flowing towards the direction of the dam lake to the north. However, the area of mottling (OST1-1a) may be associated with the channel cut and gravel lens. Above the gravel lens was an area of increased concentration of calcium nodules, which although the same colour as the surrounding layer (OST1-2), that is 7.5YR 4/4, it stands out due to the increased nodule content. This seems to correspond to the OST1-3 layer on the east side, however with more nodules. Above this is OST1-3a, which is characterised by a substantial reduction in nodules, however there is no mottling, like its possible counterpart on the east side (the top of OST1-3).

There is a channel cut at 2.5 metres, which seems to correspond to the channel cut in the east section. At the south end of the trench, there is a gravel cut at *circa* 2 metres down, again corresponding to a channel cut on the east side (see above).

Above this is OST1-5, dark greyish brown (10R4/2) sediment overlain by the top soil. OST1-4 is not evident on this side of the trench.

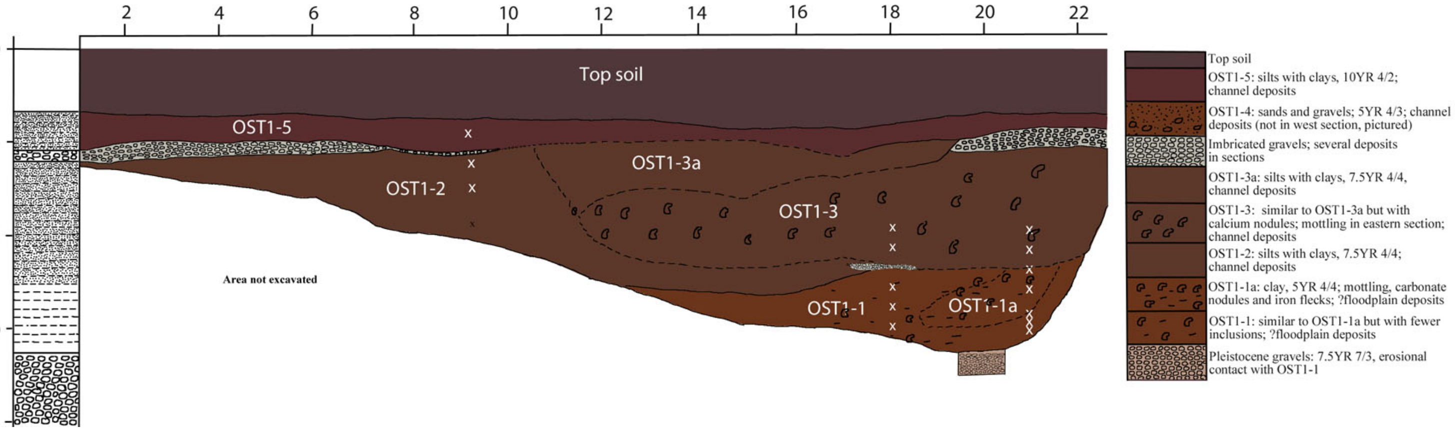

Figure 6.19: Section drawing of the western side of the deep trench, including lithology and sediment descriptions. Phytolith samples are marked with an x

Figure 6.20: Photograph of part of the western section. It was not possible to photograph the entire section. The photograph shows the deepest part of the trench, about 21 meters across. The tags indicate phytolith and sedimentary samples

Comments

The layers were very difficult to differentiate, boundaries were very blurred. There were also a lot of channel cuts, indicating a regime of channel switching, which would have eroded parts of the layers and added new sediments over time. As such, the sections were very difficult to draw mainly because there were no clear layers, outside of the channel cuts (made up of bluish limestone gravels). Slightly different colours could be discerned (reddish to brownish), with lenses of mottling and increased calcium or iron nodule content.

The boundaries are not graded as there is no change (at least visible by eye) in grain size. The boundaries seem to have been blurred, perhaps by post depositional changes. In addition, there was no trace of internal structures, i.e., lamination. These layers, therefore, have massive structures, which could be primary (i.e., result of the depositional episode) or secondary (altered post deposition). The sediments are crumbly in texture and they have a high clay content (high plasticity when wet). It should be noted that terra rossas, although a soil high in clay content, are relatively well draining soils.

The change in colouration, i.e., from reddish brown to greyish brown, could suggest a change in climatic or hydrological conditions. The reddish colouring suggests drier conditions where the sediment/palaeosol has been exposed to light. The greyer colour conditions could suggest gleying conditions where there is higher water content, as in a marshy environment.

In subsequent field seasons, cores were taken in a transect between Bakr Awa and Gurga Chiya (see Figure 6.21), and preliminary observations indicate that the sedimentation is similar across this part of the plain, gravel base (dating to the Pleistocene), followed by layers of reddish clay sediments with carbonate nodules, overlain by 1.5 meters or so of 'proper' soil formation (that is with clear soil horizons). These are further discussed in Chapter 7.

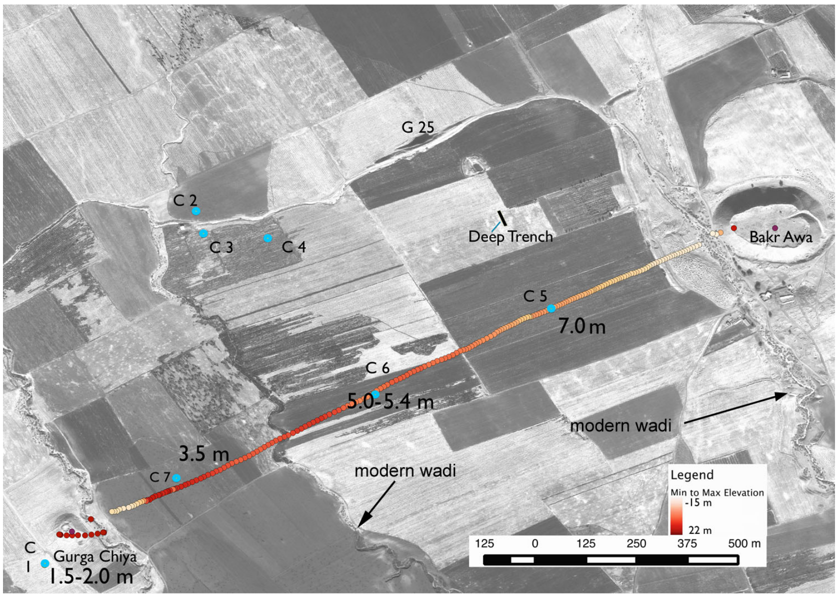

Figure 6.21: Location of the deep trench and core locations between Bakr Awa and Gurga Chiya. The dotted line indicates the Total Station transect. Modified version of map drawn by Mark Altaweel

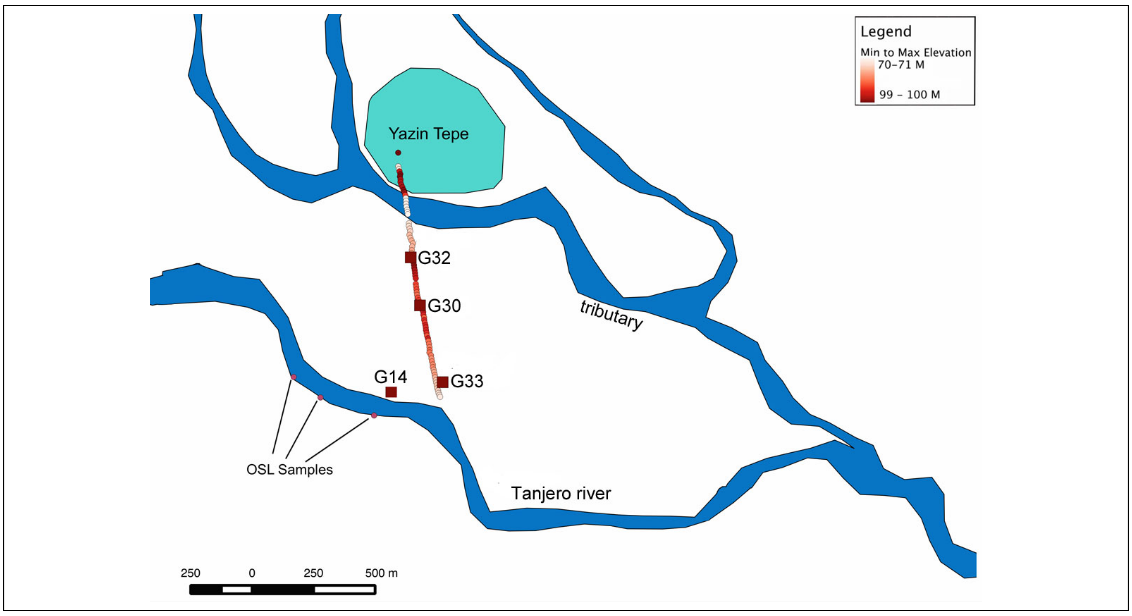

Figure 6.22: Location of the three trenches excavated at Yasin Tepe. Three OSL samples were also taken from the banks of the Tanjero. The dotted line indicates the Total Station transect. Modified version of map drawn by Mark Altaweel

A Total Station transect was also done here, results indicated that the deepest part of the plain was near Bakr Awa (which was confirmed by the cores; see again Figure 6.21).

Yasin Tepe and environs

In 2013, three trenches were excavated, drawn and sampled, G33, 30 and 32, going along a transect from the Tanjero river to Yasin Tepe (see Figure 6.22).

A Total Station transect was also done along the same line and indicates that the topography is fairly even, with a small increase in height near G30.

As the sedimentation was broadly similar in all three trenches, only G32 is illustrated here, though all three will be described (see Figure 6.23). G32 and 33 were excavated to about 4.5 meters before reaching Pleistocene gravels, the depth of G30 only reached about 3 metres as the excavator was not big enough to go further; no Pleistocene gravels were seen in this trench.

The sedimentation is not as deep in this region, as it is near Bagum and Bakr Awa. The sediments in the three trenches ranged from yellowish browns to browns, and seemed much less red that the Bakr Awa sediments. The sequences coarsen upwards, the first layer above the Pleistocene gravels is composed of mainly massive clays, whereas the layer above is composed of massive silts.

Above this layer is brown soil, with a depth of about one metre. In G32, a channel of unknown date was cut into the top soil and cuts into the second layer. Limestone rubble and pottery sherds were found in it.

In G33, there is also an area in the second layer and below the soil horizon, which is a lens of clayey silt and is a slightly different colour. The boundary was indistinct. This may have been a more waterlogged area in the terrace. Overall, the sedimentation is typical of floodplain deposits. The coarsening upwards trend indicates that the channel is shifting.

Bagum to Shamlu transect

Three further trenches were excavated in the Bagum and Shamlu area in 2013, G31, 35 and 34.

A Total Station Transect was also done along the same line as the three trenches, the deepest part of sedimentation indicated was at trench G35 (see Figure 6.24).

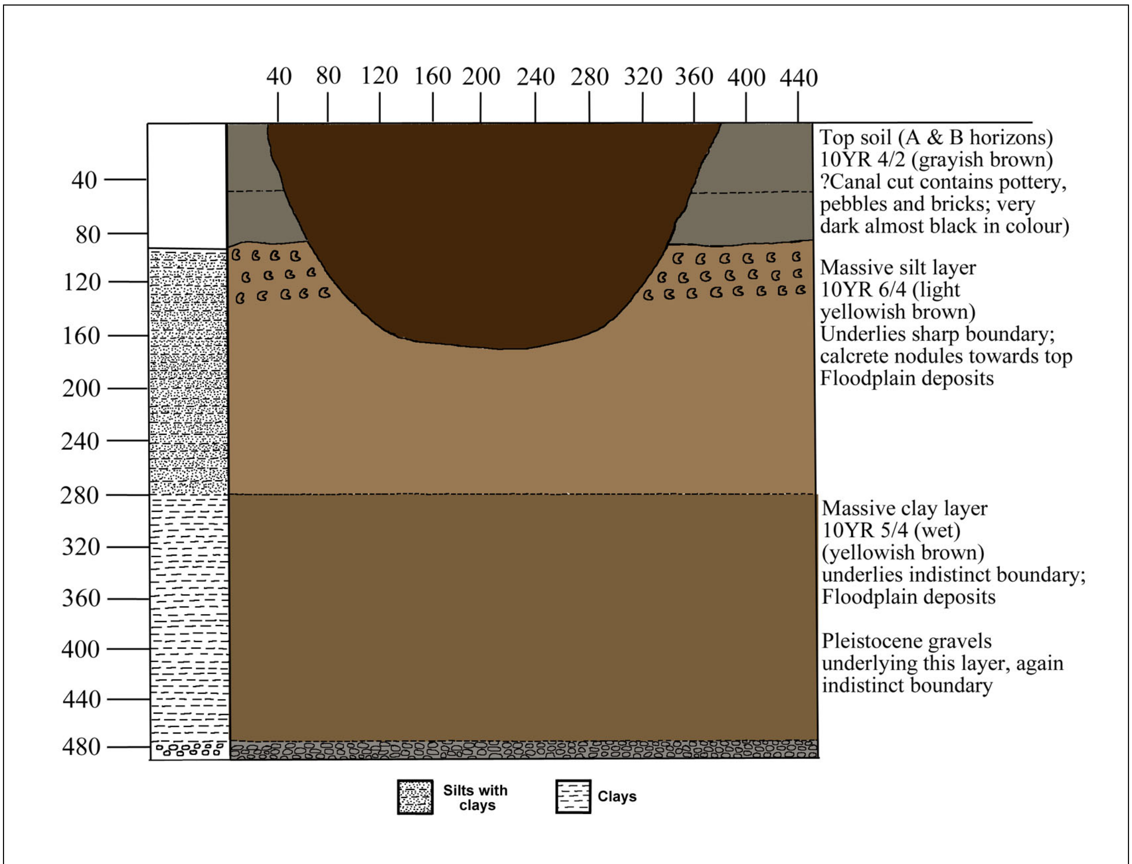

Figure 6.23: Section drawing and lithology of trench G32

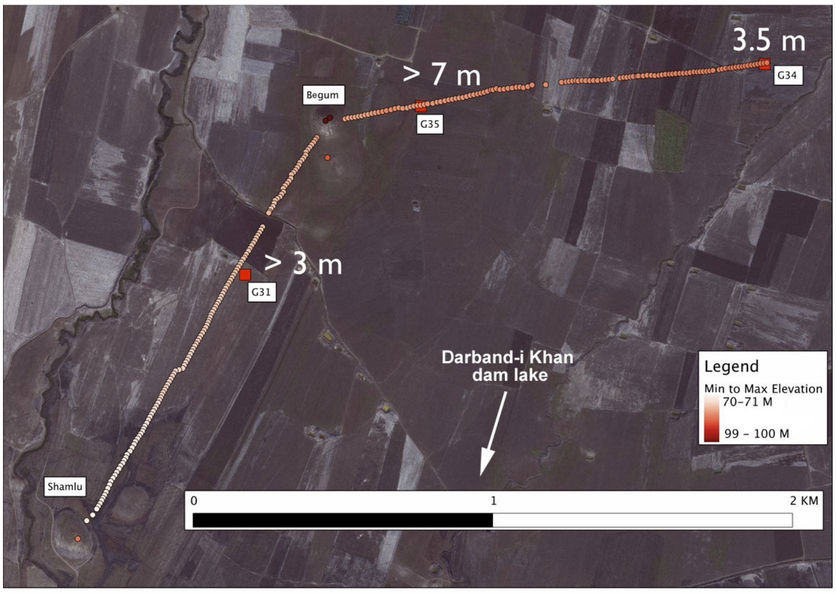

Figure 6.24: Location of the trenches and Total Station transect in the Bagum / Shamlu area. Modified map by Mark Altaweel

Figure 6.25: Photograph illustrating the high water table in the Bagum region (due to the proximity to the dam lake)

This area proved to be very difficult to record well, due to the site's proximity to the dam lake. In every trench, at about 3 to 4 metres down, water started to seep in through the sides of the trench, after excavating a bit further down, the trenches became flooded (see Figure 6.25). Nevertheless, some recording was done.

G31 contained no discernible stratigraphy. The soil was about 70cm thick, and was underlain by a massive silt layer (grey: 10YR 6/1), which contained a high percentage of clays. There was some mottling seen towards the bottom of the trench, most likely due to the more recent wetting and drying processes.

G35 also was topped by a soil profile of about 80cm thickness. This was underlain by a clay layer about 2.4m thick, which was light yellowish brown (10YR 6/4). There seemed to be a slight grain size change, to silts, below this, but it was difficult to be completely certain as water was coming into the trench. Below that, there seemed to be more gravels mixed in with the smaller grained sediments, as indicated by the sediments being excavated by the digger. However, no stratigraphy could be recorded.

Trench G34 (see Figure 6.26) was topped by about an 80cm soil layer. This was underlain by a small 40cm layer of massive silt (light grey: 10YR 7/2), containing a few calcite nodules. Under this layer was a massive clay layer with some silts (yellowish brown: 10YR 5/4). The Pleistocene gravels were encountered about 350cm down.

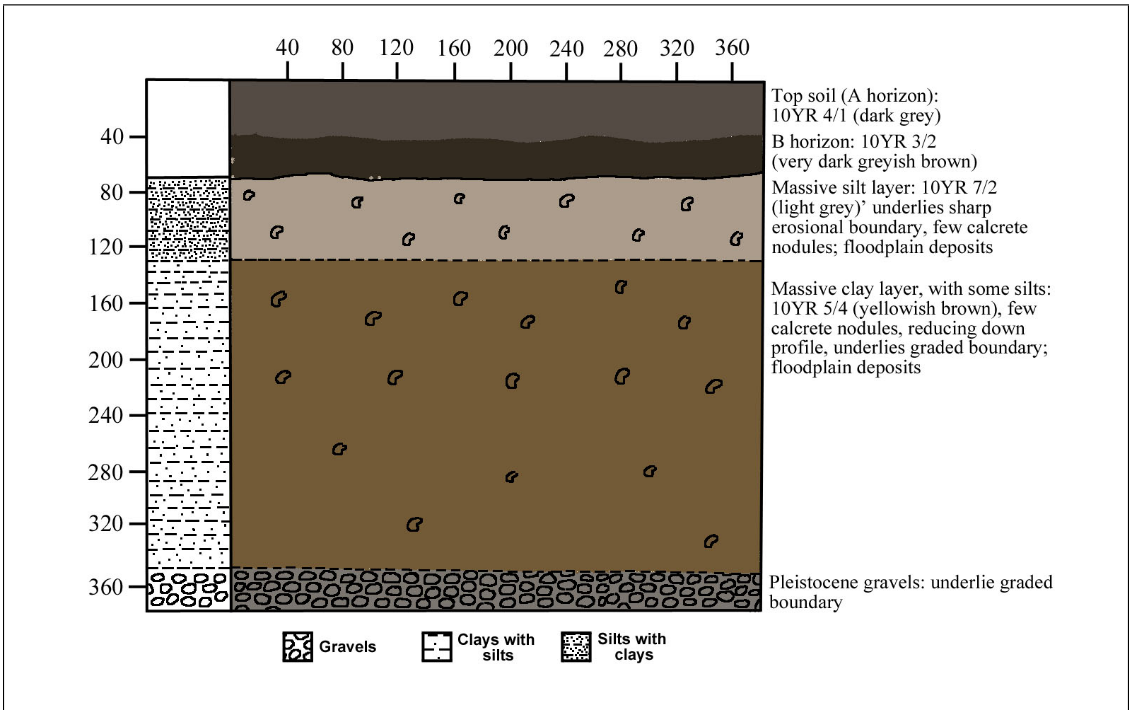

Figure 6.26: Section drawing and lithology of trench G34

6.3.2 Phytoliths

Introduction

Phytolith samples were taken from offsite contexts (the trenches excavated near Bakr Awa, at Yasin Tepe and in the environs of Bagum and Shamlu) and onsite contexts (the multi-period site of Bakr Awa). The samples discussed here include the onsite samples, deep trench samples and three samples taken from an area near the site of Yasin Tepe. These three samples were analysed as they come from sandy layers and were used as a comparison against samples from the more clay-silt layers of the deep trench. The offsite samples will be discussed first, followed by the samples from Bakr Awa.

As with the Hirbemerdon Tepe samples, raw data (phytolith counts) can be found in the appendices (Appendix I). Any histograms not illustrated in this chapter but discussed can also be found in the appendices (Appendix J).

Offsite samples – deep trench

The samples taken from the deep trench are not positively dated. Attempts were made to date the sediments from the trench and were found to be all Pleistocene in date. That indicates that this sediment is a reworked soil, with much older organic matter contained within. This also has implications for the some, although not all, of the phytoliths that were found in these samples. It is very likely that some of the phytoliths will be reworked ones, transported from the original place of soil formation in the foothills; with formation ranging from the Pleistocene into the Holocene. Other phytoliths will have been deposited more in situ. Further discussion regarding reworked and in situ phytoliths can be found in Chapter 5. Relative dates, based on pottery finds, were derived for some of the layers, but remain tentative (see Table 6.3).

Taphonomy and abundance

The total silica content of these samples, both from the deep trench and the Yasin Tepe samples, is very low, all falling below 0.5 per cent (see Appendix J). In some cases, there are comparable numbers to the Hirbemerdon offsite sam-

Sample no.	Depth (metres)	Section	Layer	Relative date	Comments
Bakr Awa					
P021	5.4	west	OST1-1	early Holocene	Pleistocene base
P004	5.1	east	OST1-1		
P020	5	west	OST1-1		
P003	4.9	east	OST1-1		
P014	5.2	west	OST1-1a		
P013	4.9	west	OST1-1a		
P012	4.6	west	OST1-2	?Pottery Neo	pottery
P002	4.5	east	OST1-2		
P026	3.8	west	OST1-2		
P025	3	west	OST1-2		
P010	2.7	east	OST1-2		
P024	2.5	west	OST1-2		
P009	2	east	OST1-2		
P019	4.5	west	OST1-3		
P011	4.3	west	OST1-3		
P018	4.2	west	OST1-3		
P001	3.4	east	OST1-3		
P023	1.8	west	OST1-5	?Achaemenid	Pottery
Yasin Tepe					
P045	1.4				
P043	1.25				
P042	1.05				

Table 6.3: Phytolith samples, with location and possible relative dates

ples, but in many cases, the numbers are much lower. Phytolith abundance (see Appendix J) was almost universally low, with numbers comparable to those of Hirbemerdon Tepe. Counts were not reached for the majority of samples (whole slides scanned), however, there was one exception, P023 which had an abundance of almost 12,000,000 (see Appendix J), higher than any sample from Hirbemerdon Tepe and comparable to onsite samples from Bakr Awa.

Taphonomically speaking, many of the phytoliths were dissolved, reworked (fractured) or both. The reworked samples most likely derive from the uplands. There were many small bits of silica in the samples, as for Hirbemerdon Tepe, much of this could be normal silica found in sediments; some of it, however, were fragments of broken phytoliths, too fragmented to identify (see Figure 5.9). The fragmenting could be related to transport and dissolution could be made worse by soil alkalinity as well as fragmentation (see Chapter 5).

Interestingly, in some of the samples, the dicotyledons and sedges seemed to be less fractured and dissolved (P023 and P002, for example), perhaps indicating more *in situ* deposition.

The percentages of multicells as compared to single cells are similar to those at Hirbemerdon Tepe, and range from about 5-18 per cent (see Appendix J).

Other silica microfossils and charcoal

Sponge spicules and diatoms were present in most of the samples in small numbers (see Appendix J), and indicate the presence of water. In P023, sponge spicules were present in larger numbers and in some samples, there were large examples (see Figure 6.27). The diatoms were mainly pennate (some Nitzschia sp., but mainly indetermined due to size and magnification), although two samples also contained centric forms (P024 and P026). While centrics tend to be more planktonic, thus indicators of deeper water, without proper identification, nothing very significant can be said of their presence. There were also some odd fibre-like possible phytoliths (see Figure 6.28), which have not yet been identified.

Figure 6.27: An image of a sponge spicule found in the offsite samples. Measurement bar is 10 micrometres

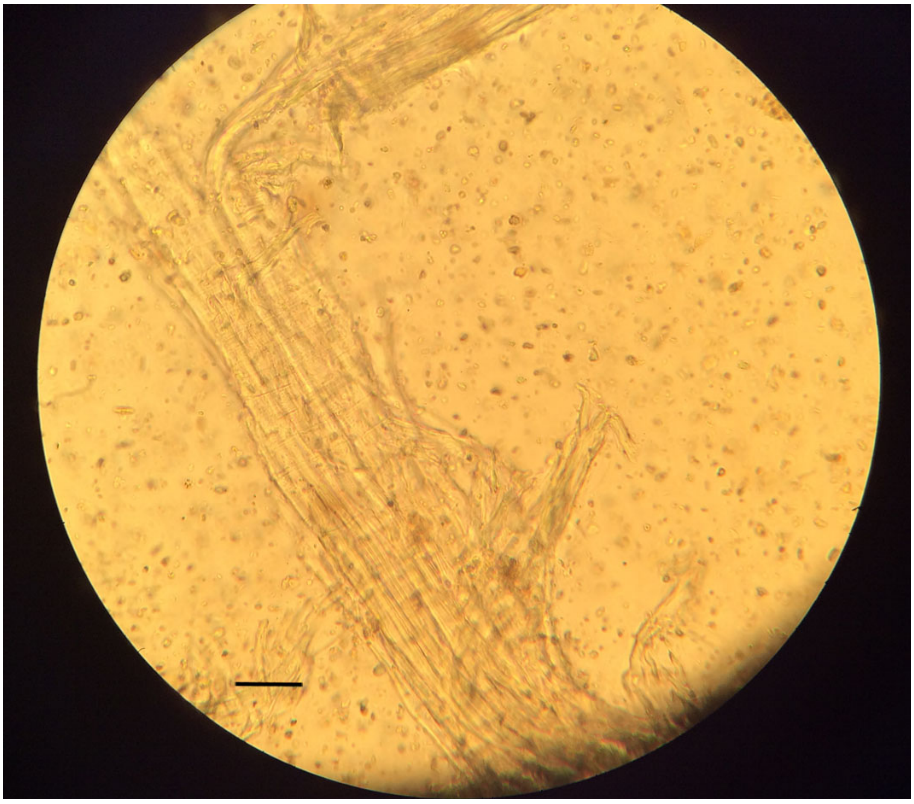

Figure 6.28: Unidentified possible multicell phytolith. Single cells were also found throughout the offsite samples. Measurement bar is 10 micrometres

Charcoal was also found in most of the samples, present as flecks (although they were not quantified). In a few samples (P014, P025), there were also burnt phytoliths.

General trends

Dicotyledons make up a substantial portion of the phytoliths, as compared with wetland and grass plants (see Figure 6.29). There do not seem to be any temporal trends, but there are fluctuations throughout the record.

The comparative values of rondels, bilobes and saddles (see Appendix J) show that for the most part, rondels dominate, indicating a temperate regime. There are some fluctuations in the numbers of bilobes (panicoids) and saddles (chloridoids), which could indicate climate changes, however it should be borne in mind that the number of phytoliths is quite low. One sample, P020, is similar to one found at Hirbemerdon Tepe (T01-5), where no rondels are present, and in this case, completely consisting of bilobes. While this could indicate some sort of change in the environment or climate, it is more likely that

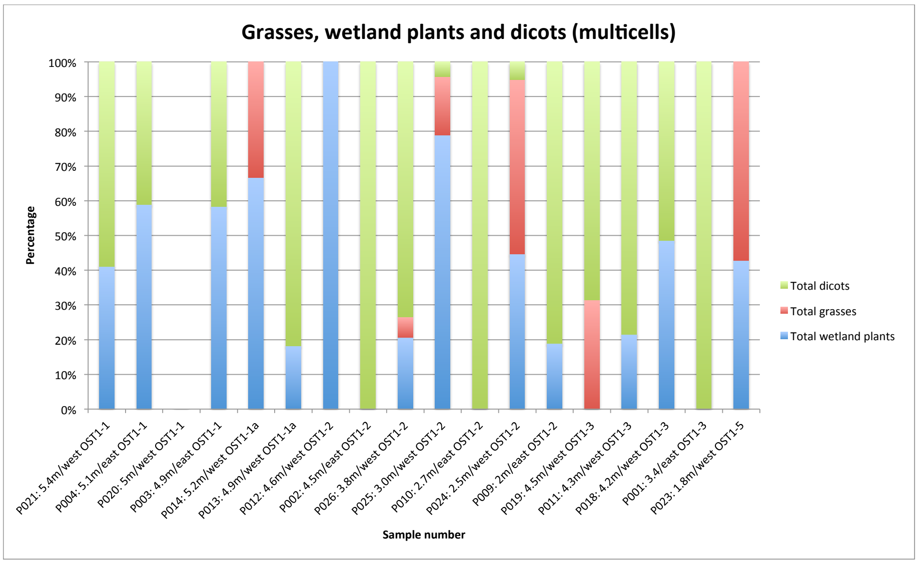

Figure 6.29: Histogram showing percentages of dicotyledons, wetland plants and grasses

as there were so few phytoliths in the sample, no rondels preserved. In fact, the raw data shows that C_3 arundinoids (saddles, bilobes and cones) are present, although in very small numbers (see Appendix I). The arundinoids are sedges, wetland plants, rondels are from grasses.

Looking at the grass and wetland plant multicells (see Appendix J), there is indication that wetland plants (including phragmites/reeds as well) also outnumber grasses in most samples, and in fact, in some of the samples, there are no grasses present. It should also be noted that wetland plants phytoliths are the least reworked as well, and that Sample P012 contained no short cells.

Jigsaws (leaf phytoliths from trees) are present in several samples, most notably P023, but also in P025, P026, and a few in P010 and P024 (see Appendix J). These could either be an indication of wetter forest conditions or channel irrigation (as discussed above), but in any case indicates increased water availability. Figure 6.30 (see Appendix J for histogram with Sample P023) also indicates the possible presence of fruit phytoliths (decorated polyhedrals), which could be an indication of fruit horticulture either in the plain or further up in the uplands.

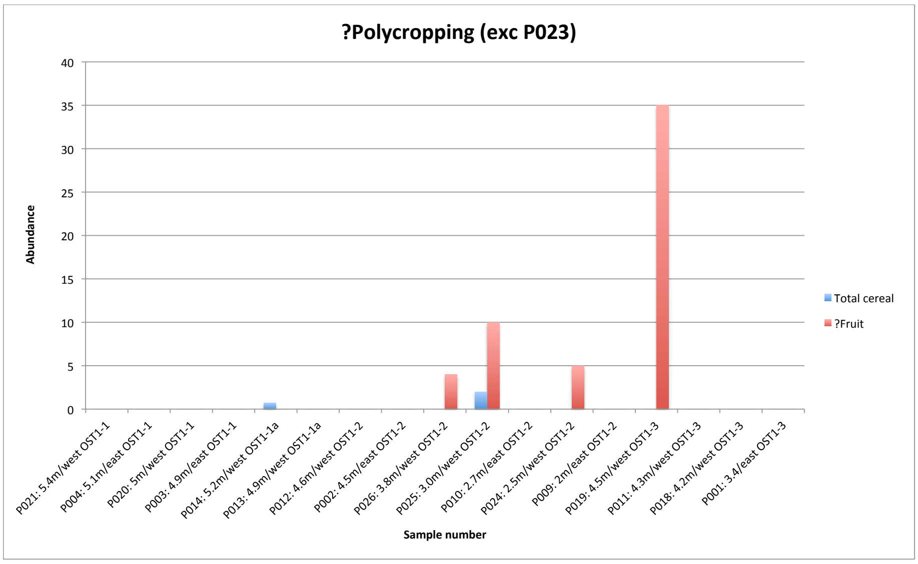

Figure 6.30: Histogram showing abundance of possible fruit and cereal phytoliths (exc. P023)

Principal component analysis was also carried out on the multicell phytolith data to see if there was any relationship between the cereals, wild grasses, wetland plants and dicotyledons. First all samples were run (see Figure 6.31), and the results indicate that there is a direct correlation between the grasses, dicotyledons and wetland plants, with the cereals being completely uncorrelated. PC1 accounted for 75 per cent of the variation, with dicotyledons, wild grasses and wetland plants having equal strongly positive correlations (0.58). PC2 accounted for 24-25 per cent of the variation, cereals are very strongly negatively correlated (-0.99). There were also some outliers: P023, P014, P025, and P024. This indicates that there is very little variation in most of the samples. The analysis was run again (see Figure 6.32), removing sample P023, which had a higher phytolith count, so as to be able to compare samples with similar counts. In this case, PC1 accounted for 89 per cent of the variation (with cereals having a weak positive correlation (0.44) and the other variables having strong positive correlations (0.50-0.52), while PC2 accounted for 9 per cent of the variation (with cereals again having a very high negative correlation (-0.86). The correlation between the wetland plants, dicotyledons and grasses is still there,

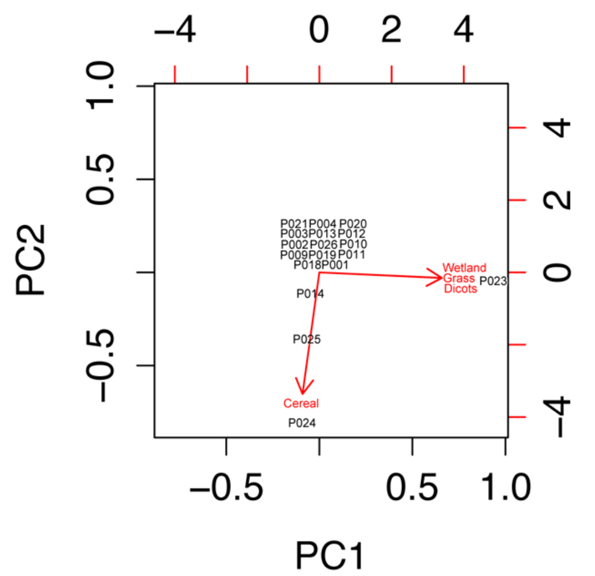

Figure 6.31: Biplot of PC1 and PC2 values showing variation between samples. Arrows indicate correlation of variables (dicotyledons, wild grasses, cereals and wetland plants). All samples included. NB: P021...P001 were clustered on top of each other and have been adjusted to improve legibility. Also wetland, grass and dicot variables are directly correlated (see text), but again text has been adjusted to aid in reading.

albeit slightly weaker. Cereals are still uncorrelated. Most of the samples still cluster together, indicating similar variation through time. However, there are still some outliers: P014, P024, P025 and P026, indicating that these samples are different to the others.

Indices (see Table 6.4)

The same caveats regarding sample size in the Hirbemerdon Tepe samples are relevant here too. The D/P values indicate that broadly speaking, the region was forested (at least in the uplands), but coverage may have varied throughout the Holocene. The Iph values are essentially useless, in that there were too few (or no) saddles, bilobes and quadralobes to obtain good results. However, the value obtained for P023 is more robust and could indicate that at this time, there was some aridity. The Ic values show some variation across time, but generally C_3 plants dominate indicating a temperate regime. The Fs index does reflect high water availability, but again with some variation across time.

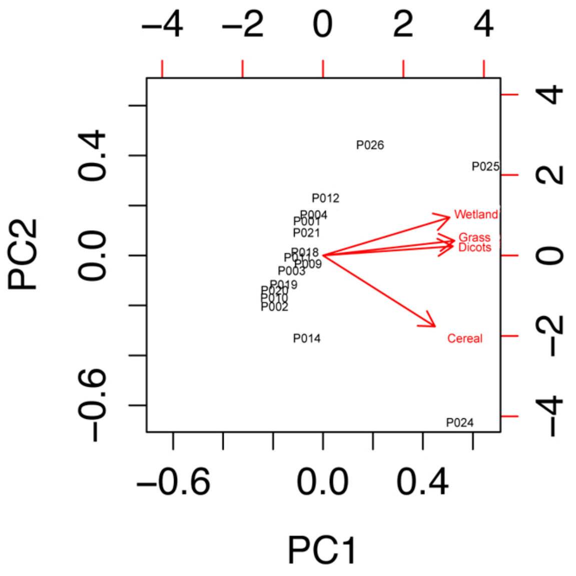

Figure 6.32: Biplot of PC1 and PC2 values showing variation between samples. Arrows indicate correlation of variables (dicotyledons, wild grasses, cereals and wetland plants). Sample P023 has been removed. NB: P018...P003 and P019...P002 were clustered on top of each other and have been adjusted to improve legibility.

Sample	P021: 5.4m/west OST1-1	P004: 5.1m/east OST1-1	P020: 5m/west OST1-1	P003: 4.9m/east OST1-1	P014: 5.2m/west OST1-1a	P013: 4.9m/west OST1-1a	P012: 4.6m/west OST1-2	P002: 4.5m/east OST1-2	P026: 3.8m/west OST1-2	P025: 3.0m/west OST1-2
D/P ratio	1.85714286	2	1.28571429	0.26315789	1.33333333	2.66666667	2.125	0.20833333	0.41558442	0.17770035
Iph	0	#DIV/0!	0	0	#DIV/0!	#DIV/0!	#DIV/0!	0	1	#DIV/0!
Ic	0.90909091	1	0.77777778	0.8	1	1	1	0.95	0.984375	1
Fs	0.375	0.16666667	0	1.2	0.44444444	0	1.33333333	0.41666667	0.26153846	0.39655172
Sample	P010: 2.7m/east OST1-2	P024: 2.5m/west OST1-2	P009: 2m/east OST1-2	P019: 4.5m/west OST1-3	P011: 4.3m/west OST1-3	P018: 4.2m/west OST1-3	P001: 3.4/east OST1-3	P023: 1.8m/west OST1-5		
D/P ratio	1.24242424	0.875	0.4	0.11111111	0.70588235	0.33333333	0.36363636	0.1369863		
Iph	#DIV/0!	0	1	#DIV/0!	1	0	#DIV/0!	1		
Ic	1	0.96551724	0.97368421	1	0.875	0.90909091	1	0.97619048		
Fs	0.76190476	0.15384615	1.48	0.47058824	2	0.42857143	0.54545455	0.44680851		

Table 6.4: Table with the indices results

No large multicell phytoliths (10+ conjoined cells) were found in these off-site samples.

Yasin Tepe

As stated before, these samples cannot be temporally correlated to the deep trench samples, they are, however, Holocene period samples and come from sandy alluvial layers. These were analysed to see if there were differences in preservation and abundance between samples from clay or those from sandy layers.

The silica content was comparable to the other samples (see Appendix J). Single cell counts were reached in all three samples, so there were consistently more phytoliths than in most of the deep trench samples, but still few in number as compared to the onsite samples. There were still many dissolved or weathered and fragmented phytoliths, indicating again that many of the phytoliths may have been transported from elsewhere or possibly affected by high alkalinity soils. There did not appear to be any discernible trends.

There were very very few diatoms and sponge spicules present in the samples (and these probably were transported from elsewhere; see Appendix J). No charcoal or burnt phytoliths were seen in these samples.

Very few multicells were found in these samples, and they are dominated by monocotyledons (there are far fewer dicotyledons in these samples). In addition, rondels dominate the record, with very few saddles or bilobes found. Grasses and sedges have similar numbers, although there appear to be more grasses (rondels) in sample P042. There were also some jigsaws present, although few in number. See Appendix J for relevant histograms.

Onsite samples: Bakr Awa

Evidence presented here, as with the Hirbemerdon Tepe samples, will elucidate on resource use and site economies, with some background environmental signals, which can be compared with the offsite samples. These samples range in date from the Early Dynastic period to the LBA (a similar time span to Hirbemerdon Tepe).

Taphonomy and phytolith abundance

The silica content of the samples varied considerably, ranging from about 2 per cent to 15 per cent (see Appendix J). Several samples had much higher percentages: 114/2293 had around 42 per cent, 101/2232 about 38 per cent, and 115/2306 had about 70 per cent. 115/2306 was a white layer found on the pavement of the Akkadian/post-Akkadian shrine room – the whiteness may be the result of the silica.

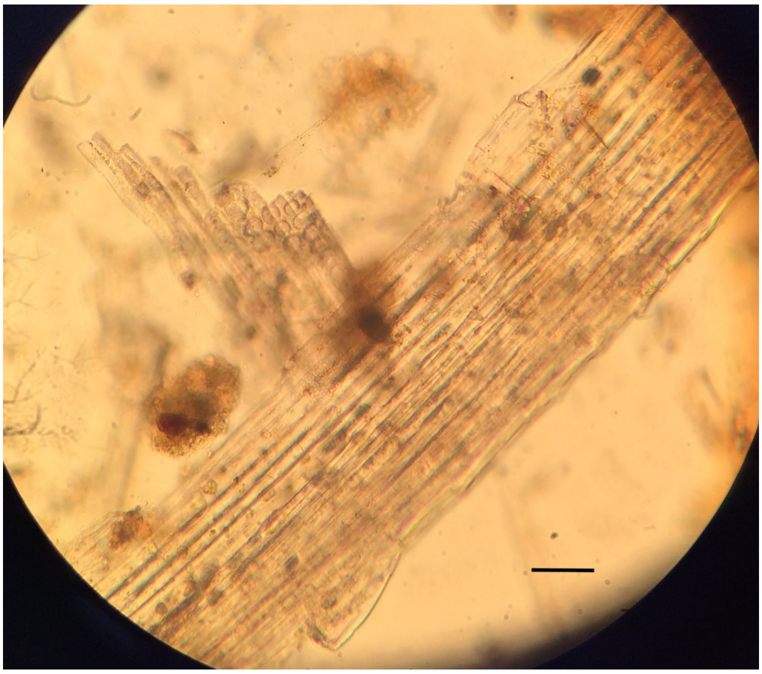

Figure 6.33: Image of a large stem multicell. Measurement bar is 10 micrometres

The phytolith abundance also varied, ranging from 400,000 to about 800,000 phytoliths per gramme. 115/2306 again stands out, with an abundance of over 25,000,000 (Appendix J).

Single cells and multicells were both found in the samples and the multicells ranged from about 5 per cent to 50 per cent of the total, with many ranging from about 15 to 25 per cent, higher than in the offsite samples (see Appendix J). In many of the samples, there were larger multicells (10+ conjoined cells to 50+ conjoined cells and up to 100+; see Figure 6.33). Percentages are tabulated in Table 6.5. This could have important implications for water availability (see Chapter 7).

The preservation of the phytoliths was good, and far better than the offsite examples. Some samples did have some dissolved or weathered specimens.

Other silica microfossils and charcoal

Diatoms are present in small numbers in most of the samples, and sponge spicules in one of the samples (107/2272; see Appendix J). Most of the diatoms were pennates, in many cases *Hantzschia amphyoxis* (a terrestrial species found on mosses). There were also some centric forms. The diatoms are most abundant in one sample, 111/2279, the Akkadian fireplace in the shrine room. There

Sample and date	112/2317: EBA floor (ED)	114/2293: EBA floor (ED/Akk)	109/2269: Akkadian floor (with shrine)	115/2306: white layer on stone pavement of shrine	111/2279: Akkadian fireplace (near shrine)
High water availability/irrigation	yes (100+)	yes 100+	0	yes 100+	yes 100+
Sample and date	110/2274: Akkadian fireplace (near shrine)	101/2232: Late 3rd millennium floor level	17/2217: Ur III ashy floor	107/2272: Under OB grave, room 102	106/2264: Oldest OB floor, room 103 OB house
High water availability/irrigation	0	yes 10 percent	yes 16 percent	0	yes 50+
Sample and date	108/2264-1: OB pot contents, from oldest OB floor	16/2218: OB floor (from section)	21/2205: Edge of OB floor	20/2205: Depression in OB floor	18/2205: OB pebble floor - by wall
High water availability/irrigation	0	<10 percent	yes 50+	yes 10 percent	yes 10 percent
Sample and date	19/2205: OB pebble floor - centre	105/2238: LBA floor	102/2227: LBA floor	104/2237: LBA floor	103/2236: LBA floor
High water availability/irrigation	yes 100+	yes 100+	? Long LCs	<10 percent	<10 percent
Sample and date	113/2294: LBA floor	117/2294: LBA floor	02/1159: LBA/IA floor		
High water availability/irrigation	<10 percent	<10 percent	<10 percent		

Table 6.5: Irrigation index, based on methodology developed by Rosen and Weiner (1994)

is no correlation (0.28) between wetland plants and diatoms, which indicates that they did not come into the record together.

There was very little charcoal in the samples, however, there were some burnt and even melted phytoliths in many samples (see Figure 6.34), indicating burning and high temperatures somewhere in the vicinity of those contexts (see Chapter 7).

General trends

The samples range in date from Early Dynastic (EBA), through Akkadian, Ur III, Old Babylonian and LBA. Samples were also taken from the Iron Age and Islamic periods, but were not analysed as they fall outside the purview of this thesis. There do not seem to be any obvious temporal trends in these samples. Generally speaking, cereal, weeds, wetland plants and dicotyledons are all present throughout the different periods, and variance seems to be more dependent on context.

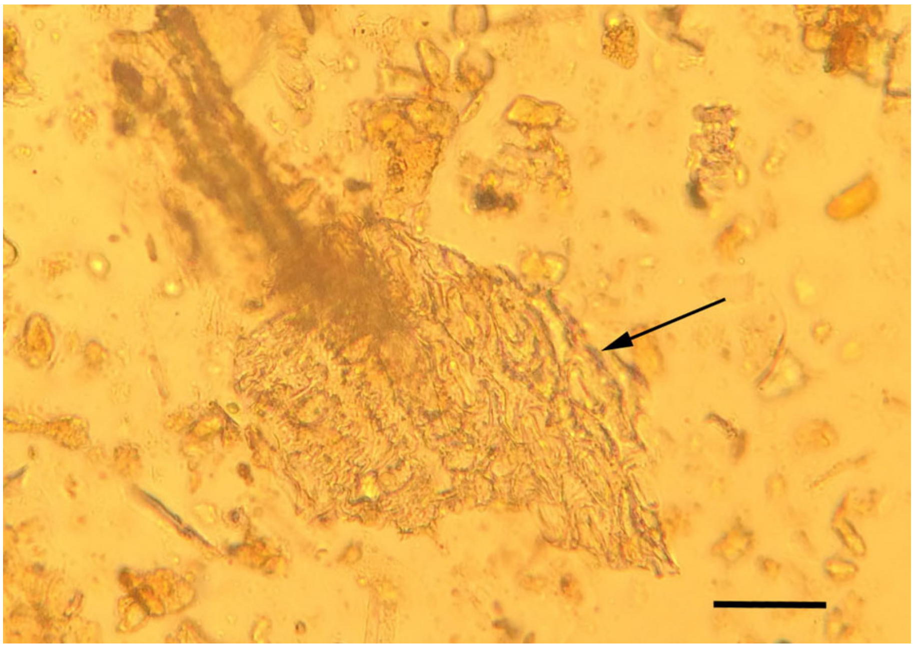

Figure 6.34: Image of a *Phragmites* sp. multicell. The arrow indicates the stomata that appear to be warped and perhaps melted. There were many phytoliths that exhibited this feature. Measurement bar is 10 micrometres

Monocotyledons, of course, outnumber dicotyledons (see Appendix J). Dicotyledons are present in percentages ranging from 5 to 15 per cent. There may be some tapering off of dicotyledon numbers in the later LBA levels, however, this could also be context related as these are all floor levels. C_3 rondels also dominate the record, reflecting the trends of the offsite samples (see Appendix J). These could also reflect the use of cereals on the site. There are some increases in the number of saddles and bilobes in certain contexts, probably signifying contextual use rather any climate signals. In any case, it is difficult to determine climatic signals with any certainty from onsite materials as the phytolith record reflects material that is mostly (although not completely as in the case of weeds) intentionally brought on to the site.

Cereal husks were difficult to identify in terms of species/genera. There are certain contexts where there were spikes in the numbers of husks and straw, including the EBA floors, late third millennium floor, an OB floor, and several LBA floors (see Figure 6.35). Other samples had few cereal remains, perhaps suggesting a different room function.

There is a fairly strong positive correlation between agricultural weeds and barley (0.93097714) especially from the EBA to the Old Babylonian, and so it would seem that the barley came in together with the weeds. There is a very weak correlation between the wheat and weeds (0.686655789) as well as between wheat and barley (0.779161146). The correlations done by time period (e.g., ED or OB), are fairly similar, although there is a difference in the Akkadian period, when there is a weak negative correlation between barley and weeds for instance (see Table 6.6). These correlations could help to elucidate whether barley came in as a weed, which could indicate either that barley was not consumed or that naked barley was used (whose husks would not be seen in the phytolith record). It might also be possible to determine if the agricultural weeds came in as weeds or as fodder/bedding.

Wetland plants are found throughout the existence of the site, and consist mainly of sedges, although some phragmites/reed phytoliths were identified in a few samples (particularly 101/2232, a third millennium floor level; see Figure 6.36). In fact this sample had the highest number of wetland plant phytoliths. The presence of these throughout the temporal range indicates that continuing availability of these plants. Some of the OB pebble floors also had few wetland plants. This could be because the floors were kept clean or items such as baskets and mats were not used in this space.

Dicotyledons were also found throughout the samples, but were especially high in sample 115/2306, the white layer on the shrine pavement (see Figure 6.37). Some fruit phytoliths were tentatively identified as well as leaf and wood/bark single cells. Generally speaking, leaf phytoliths outnumbered the wood/bark ones. Again the OB pebble floors had few dicot phytoliths.

6.4 Comments

Some trends, even if in some cases tentative, can be seen in both the sedimentary and phytolith records. At Hirbemerdon Tepe, the sedimentary record indicates alluviation throughout the Mid-Holocene, with some pauses. The phytolith record indicates a use of different resources from the local environment, as well as possible changing agricultural strategies and increasing use of the terrace.

CORRELATIONS	
wheat/barley	0.77916115
Barley/wild grass	0.93097714
Wheat/wild grass	0.68665579
Cereal/wild grass	0.91341477
barley/wheat ED	1
barley/wild grass ED	1
wheat/wild grass ED	1
cereal/wild grass ED	1
barley/wheat AKK	-0.3333333
barley/wild grass AKK	-0.6845406
wheat/wild grass AKK	0.36766436
cereal/wild grass AKK	0.42658094
barley/wheat URIII	#DIV/0!
barley/wild grass URIII	1
wheat/wild grass URIII	#DIV/0!
cereal/wild grass URIII	1
Barley/wheat OB	-0.0645194
Barley/wild grass OB	0.95821263
Wheat/wild grass OB	-0.139169
Cereal/wild grass OB	0.4914865
Barley/wheat LBA	#DIV/0!
Barley/wild grass LBA	#DIV/0!
Wheat/wild grass LBA	0.5022936
Cereal/wild grass LBA	0.95725731

Table 6.6: Table showing correlations between wheat, barley and agricultural weeds

The Bakr Awa sedimentary record indicates heavy alluviation occurring throughout the Holocene, and in the Bakr Awa region, where the deep trench was located, a large channel with associated wetlands. There are also hints of changing agricultural strategies, and onsite, there may be indications of changing crop preferences.

These results will now be brought together for each site, and trends will be discussed in more detail in Chapters 7 and 8.

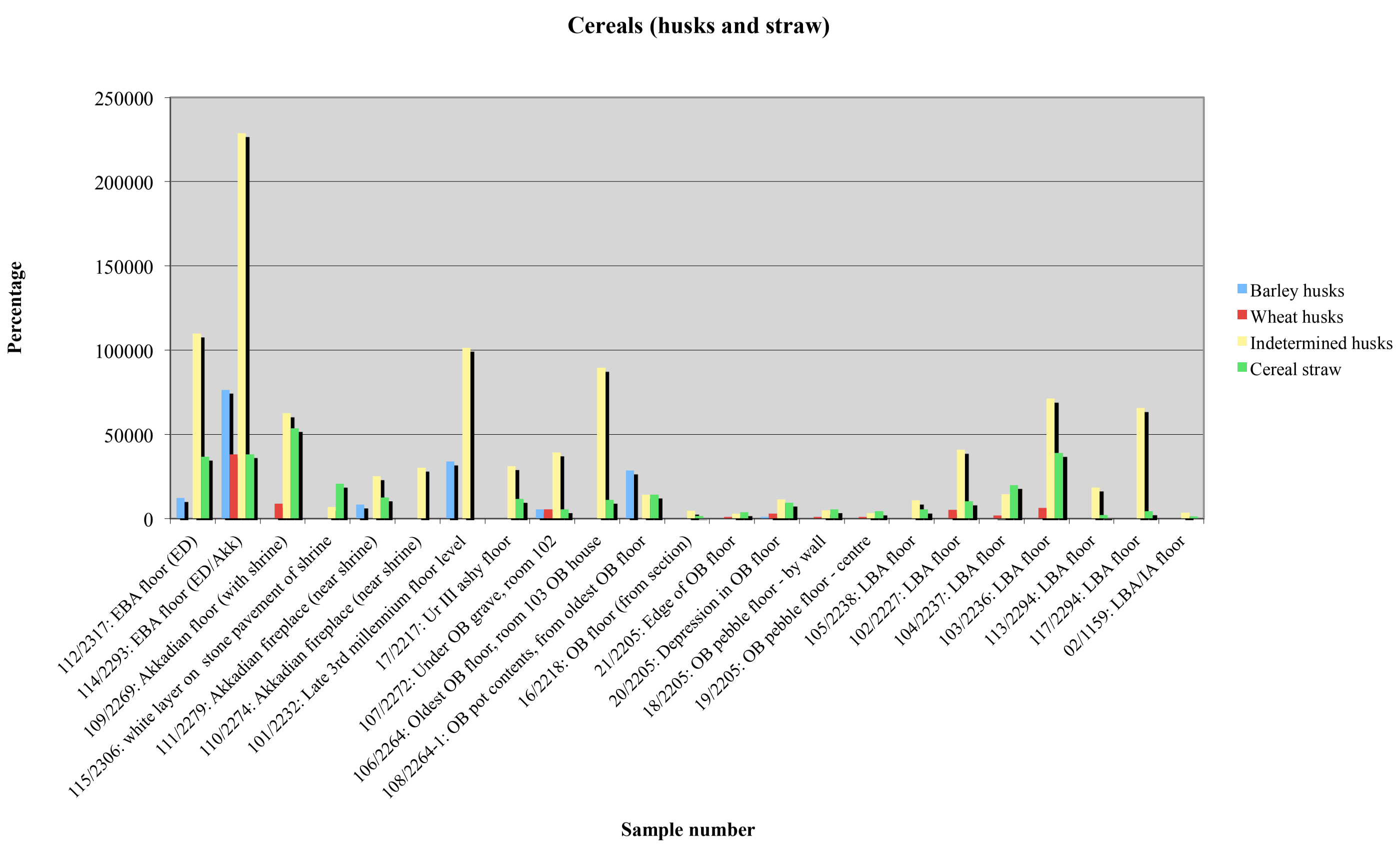

Figure 6.35: Histogram showing the abundance of wheat and barley husks and straw

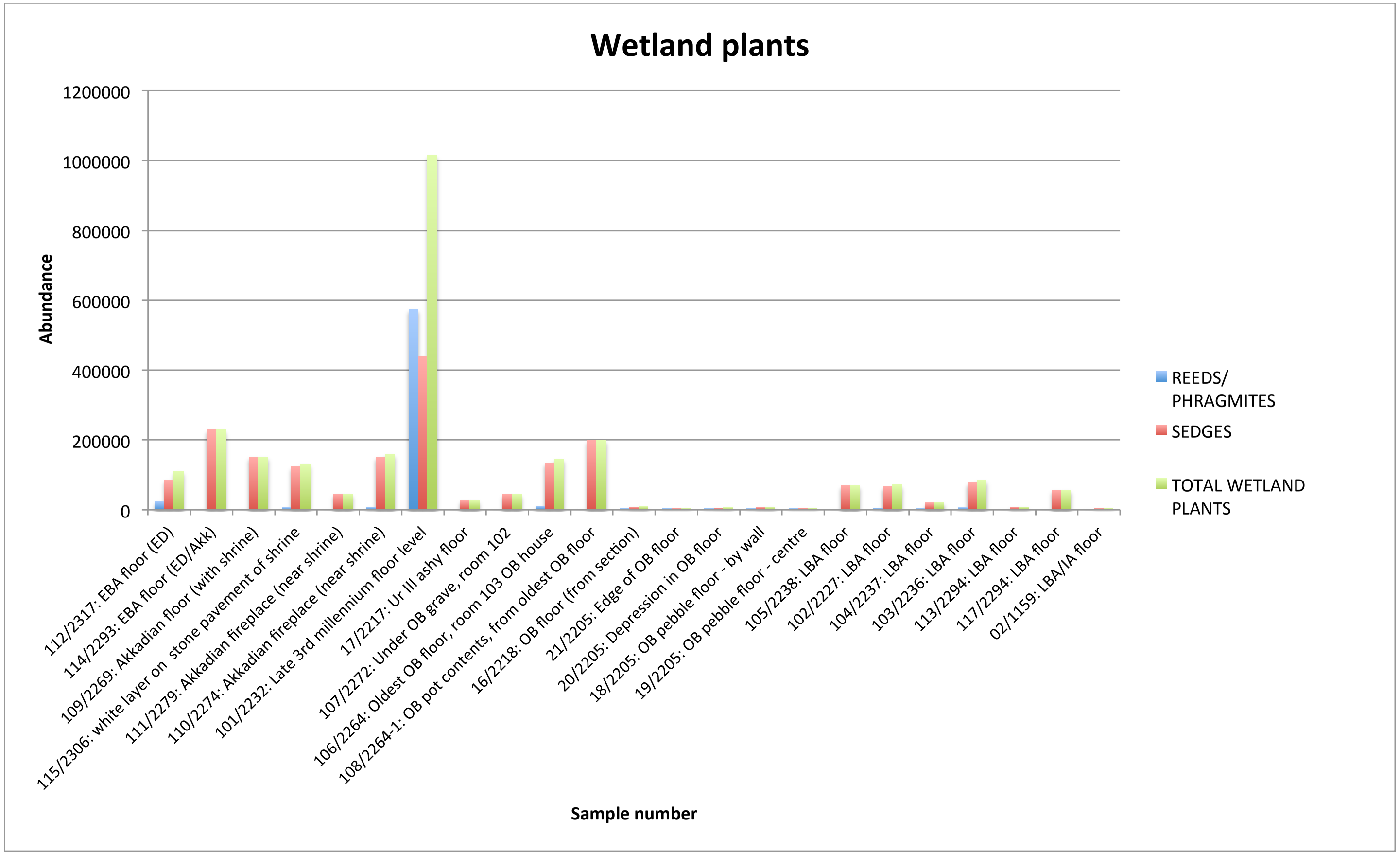

Figure 6.36: Histogram showing the abundance of phragmites, sedges and total wetland plants

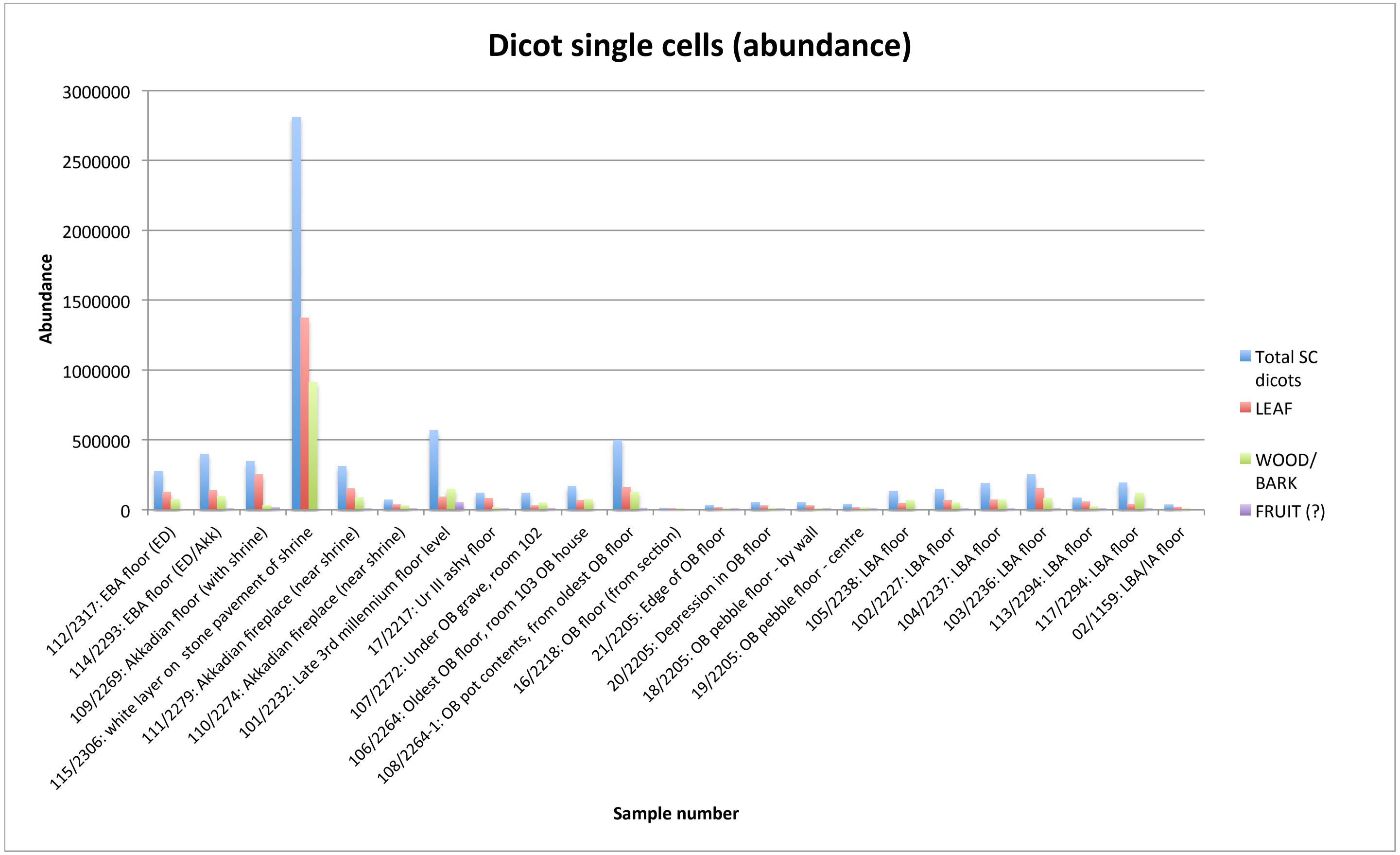

Figure 6.37: Histogram showing the abundance of different dicotyledon phytoliths

Part IV

Interpretation and concluding remarks

Chapter 7

Interpretation I: General trends in local environmental change

7.1 Introduction

The interpretation of the results will be divided into two sections. The first section, presented here, will focus on the first two research questions: 1) How are local and regional environmental changes reflected in the sedimentary and phytolith records? and 2) What resource and land use patterns can be discerned in the onsite and offsite proxy data? A discussion on general trends will follow. The second section (Chapter 8) will focus on the third research question: How can sedimentary and phytolith evidence be used, in conjunction with other datasets, to elucidate on human modification of the environment and ecological and cultural inheritance as posited by cultural niche construction theory?

The two sites presented here (Hirbemerdon Tepe and Bakr Awa) are situated away from the 'core' of southern Mesopotamia. However, they are still central, acting as gateways, places of exchange of goods and ideas between southern Mesopotamia and the Caucasus and Anatolian region (Hirbemerdon Tepe) and Anatolia and Iran (Bakr Awa), as discussed in Chapter 3.

The two sites are geographically very similar. Hirbemerdon Tepe and Bakr Awa are located on fertile alluvial plains in upland regions (the Taurus and Zagros mountains respectively). The range of microenvironments and availability of resources and use of agricultural and resource management strategies have ensured a certain level of in-built resilience in these two sites.

7.2 Hirbmerdon Tepe and environs

7.2.1 Introduction

Hibermerdon Tepe is located in a karstic upland environment, on the bank of the Tigris river. As discussed in Chapter 3, the site itself is built into a karstic basin-type feature on top of a Miocene outcrop, the side of which affords an expansive view up and down the Tigris. Currently the river is incising, although the effects of this are modified by the dam located upstream near Batman. Below the tell is a small alluvial plain, where parts of the lower town and outer town were located. The immediate area is surrounded by Pleistocene terraces and the foothills of the Taurus mountains.

A mixed economy of agriculture and pastoralism is practised here: the alluvial plain is used for agriculture and grazing, grazing also takes place in the uplands. There are now very few trees in the uplands and the climate is characterised as Mediterranean, with cold winters and hot dry summers. Most of the precipitation currently falls as snow in the winter months, although there is some occasional summer rain. This is a landscape which has been modified through human agency and natural climate variation, and may not reflect what it was like millennia ago.

At the beginning of the third millennium BC, the Early Bronze Age I, a small rural settlement was founded on this outcrop of limestone (see Laneri *et al.* In press). Earlier Chalcolithic and Neolithic settlements were located on the alluvial plains and Pleistocene terraces (see Ur 2007). By the Middle Bronze Age, this small site had expanded to include a monumental complex, with some sort of 'ceremonial function' (Laneri *et al.* In press). The interesting aspect to this expansion in the very early MBA is the fact that the site expanded in a period of changing climatic conditions, which may be related to how the inhabitants managed their environment, and indeed changed it to suit their needs and ensure sustainability.

7.2.2 Hydrological and vegetation history of the 'Mid Holocene terrace'

As discussed in Chapter 3, five Quaternary river terraces have been identified in the Bismil-Batman region, T1-T5 (Doğan 2005a). T1-T3 are Pleistocene in date, and T4 and T5 are Holocene period. The terraces were created through deposition of alluvial sediments, as well as vertical movement in the region (Tolun 1962). Upthrust is still continuing into the present (Tolun 1962), explaining some of the heights of the older terraces; there are several faults just due northeast of the site (see Chapter 3).

Hirbemerdon Tepe is on the edge of the Batman-Tigris confluence and just outside Doğan's study area. Four terraces were located in the immediate environs of Hirbemerdon Tepe (T1-T4). Since terraces 1-3 are Pleistocene in age (see Doğan 2005a), they will not be discussed in detail here. These Pleistocene terraces are located away from the current channel of the Tigris, and have been much eroded by later Holocene channel incision and switching and appear mainly as higher elevations in the distance (see Figure 3.8).

T4 is a Holocene terrace, which is characterised by Doğan (2005a) as being about 4-5m in height and having a coarse gravel base overlain by silt layers and lenses. Agriculture is practised on this terrace and usually abuts the earlier T3 terrace (the Tigris would have incised T3 before the creation of the new terrace). The sedimentary characterisation does vary across the region, with sequences of aggradation and possible flash flooding being reflected differentially, depending on local factors such as stream power, incline and vegetation cover.

The T4 terrace was identified because of its height, its location (abutting the earlier T3), but most obviously because of the Chalcolithic and later finds found within and on top of the terrace. The terrace edge has been incised by irrigated water flowing back into the Tigris (see Figure 3.4), desiccation and subsequent collapse of the sides. However, the terrace edge was still useful as there was some stratigraphy visible in the sections, which could be recorded and sampled.

One sedimentary episode was apparent in most of the terrace sections – a pinkish-coloured flash flood layer towards the top of the terrace edge (about 1.5 metres from the top; see Figure 7.1). In 2007, Jason Ur and his team discovered this flood layer in section and dated it to the Chalcolithic or just after (Ur 2007), based on finds and possible architectural features. Unfortunately, this particular section could not be located in the next season (2008) by myself and a member of Ur's team, Guido Guarducci. This section was probably eroded away by water action and soil slump, which indicates the highly erosive nature of these terrace edges and danger to the preservation of archaeology embedded within. We did, however, find comparable sections, as this layer could be found almost everywhere in the terrace edge. However, the material finds within the sections varied in age and included a stone mortar, a core, flint tools, RBWW (Red Brown Wash Ware – a cultural marker in the Middle Bronze Age Upper Tigris region: Laneri *et al.* 2008) and possibly later (Iron Age) finds. The flood layer thus dates to a later period (post-MBA and possibly post-IA).

Figure 7.1: Section on the terrace edge. The flood layer is the light stratum indicated by the arrow

In any case, what this indicates is that this terrace is most certainly Doğan's T4, based on the Mid- to later Holocene finds. Furthermore, this terrace is the so-called 'Mid-Holocene terrace', which is found across the Near East, for instance, in the Urfa plain, at Kazane Höyük (Rosen 1997) and Titriş Höyük (Algaze *et al.* 1995), at various sites in Syria (Wilkinson 1999, Courty 1994) and in the Levant (Rosen 2007).

The identification of this terrace was important as it contains information about Holocene hydrological and vegetation history of this particular part of Turkey, which in turn can give indirect information on past climatic regimes and environmental changes. In addition, this data can be compared to terraces across the Near East in order to compare and contrast local climate and environmental change. The detailed descriptions of the sedimentary sequences and phytolith evidence can be found in Chapter 6 and the Appendices.

The three sections (T01, G01 and G02) described in the previous chapter will now be correlated (see Figure 7.2) and a tentative history of the formation of this terrace in this part of the Tigris river will be given and compared with other regions.

Doğan (2005a) describes three cycles of alluviation in the Bismil-Batman region. The first occurs in the late Pleistocene through the early Holocene; the second occurs during the Chalcolithic (Mid-Holocene) and the last occurs just after Early Bronze Age I.

The sedimentary evidence in this region seems to be a bit different. The stratigraphic sections have been described and the facies therein have been broadly grouped into four cycles: 1. Late Pleistocene / Early Holocene; 2. Early to Mid-Holocene (Neolithic to Chalcolithic); late Mid-Holocene to early Late Holocene (EBA through MBA); and 4. Late Holocene (post-MBA), based on the associated archaeology from the Outer Town, comparisons between the facies of the sections and descriptions of the Mid-Holocene terrace between Bismil and Batman (Doğan 2005a) and at Kazane Höyük (Rosen 1997) and Titris Höyük (Algaze *et al.* 1995) in the Urfa plain.

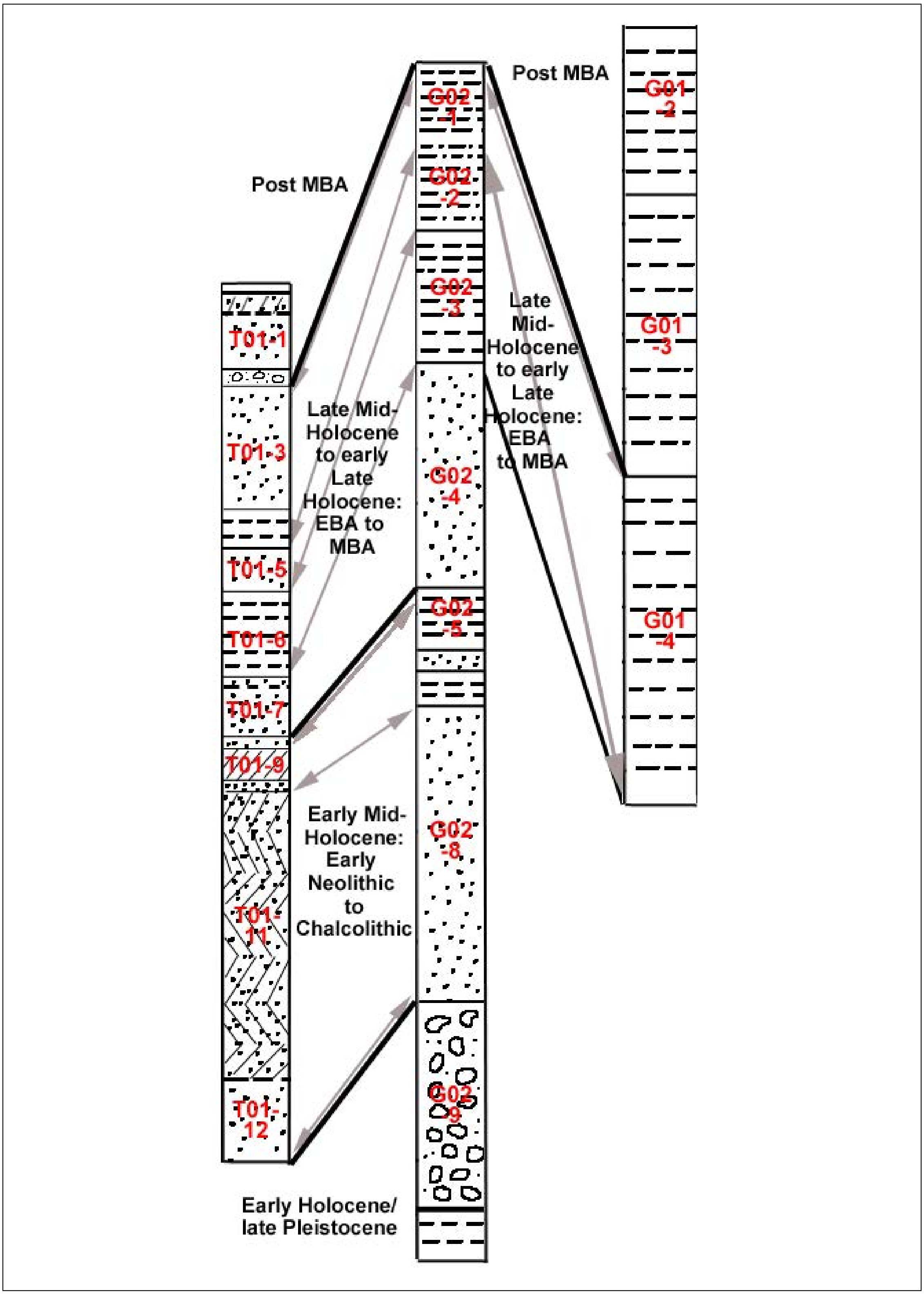

Figure 7.2: Correlation of the three sections recorded in the terrace at Hirbemerdon Tepe. The grey arrows indicate the sedimentary units which are broadly contemporaneous; the black lines show the broad correlation of time periods

The sedimentary evidence is also combined with the phytolith evidence and any available archaeological evidence. For this section, most of the phytolith data comes from offsite contexts (nine samples: see Chapter 6 and appendices for discussion and graphs), but there will also be reference to some onsite data as well, where applicable.

Late Pleistocene to Early Holocene

At the bottom of irrigation section G02, there are two facies overlain by a sharp erosional boundary (see Figure 7.2 as well as Figure 6.6). The lowermost facies (G02-10) is composed of pale yellow (2.5Y 7/2) muds with intercalated sands, indicating floodplain deposits. This is covered by G02-9, brown (10YR 5/3) sediment composed of poorly sorted sands and granules with intercalated muds, which could indicate increasing instability in the hydrological system. The erosional boundary indicates that there was a period of river incision (a cessation in river aggradation) for a period of time, likely due to increased aridity. This may be the end of the Pleistocene or the so-called 8.2KY event. Generally speaking, the 8.2KY event is characterised by sudden increased aridity, and coldness in the more northern latitudes (see Alley and Agustsdottira 2005), although the Lake Van records indicate increased humidity at 8.2KY (Wick *et al.* 2003). The apparent disagreement in proxy records may be due to dating issues surrounding palaeoenvironmental evidence (discussed above in Chapter 2 and see: Hormes *et al.* 2009, Roberts *et al.* 2011a).

Phosphate, loss on ignition and magnetic susceptibility readings for G02-9 were all lower in relation to other layers, and indicate no real soil formation processes, however, as discussed in Chapter 5, soil horizons in alluvium can sometimes be hard to detect.

The boundary here is abrupt, and unparalleled in the rest of the sedimentary record. There also does not seem to be a parallel in the Doğan (2005a) research area. In any case, this boundary indicates that there was a substantial change in conditions, and there was a period of river incision and land surface erosion. Tentatively, these bottom two layers are identified with Doğan's first cycle, which are superficially similar and underlie later Neolithic sites. He states that the first cycle of alluviation for T4 began in the late Pleistocene/Early Holocene. His dating evidence is relative and archaeological: these sediments underlie the EBA and IA site of Aşaği Salat and Neolithic sites are located on top of this deposit (p. 78). These sediments are characterised as being 'yellowish fine sandy silts', which overlie Pleistocene gravels. No gravels were found in these sections, but this may be due to the fact that the sections did not go deep enough, or that these sediments reflect floodplain deposits as opposed to channel deposits. In addition, no sedimentary structures are described in Doğan's paper, so it is difficult to ascertain if these are high magnitude flash flood or seasonal flooding layers.

There does not appear to be a corresponding deposit at Kazane Höyük, where alluviation seems to restart later, in the Mid-Holocene. This is most likely due to the differences in hydraulic regimes between the Tigris and the smaller tributary, Karakoyun Cay at Kazane Höyük. At Titriş Höyük, a settlement located in the upper Euphrates valley, the sedimentology record is similar to that of Kazane Höyük (Algaze *et al.* 1995).

Unfortunately, there is no archaeological or other evidence to support this conjecture. There is evidence of Neolithic settlement in the terrace (as found during the course of archaeological survey: Ur 2007), however, limited excavations on the terrace did not uncover further evidence of Neolithic habitation. At this juncture, it is only possible to say that these layers predate the more securely dated Chalcolithic and later layers, they superficially resemble Doğan's EP/EH sediments and there are no other corresponding layers at Kazane Höyük and Titriş Höyük.

Early to Mid-Holocene (Neolithic to Chalcolithic)

The Tigris began to alluviate again, at some point after (tentatively) the 8.2KY event. In the gully section G02, these sediments are found in layers G02-8 to 5 (which is a fining up sequence, thus indicating a general slowing down of the hydrological system), and there are corresponding layers in the terrace trench (T01: see Figure 7.2 and Figure 6.2), layers T01-12 through 8. There appears to be regular alluviation to begin with, followed by a period of instability towards the end, with an overall trend towards a decrease in stream power.

In the terrace trench, the two layers 12 and 11 both indicate regular alluviation. The laminations in the lower layer are not as obvious, but they are there, suggesting some sort of post-depositional reworking (and perhaps a period of stability?). The layer on top of that (T01-11) more obviously shows regular alluviation with its cross-stratified sands.

The corresponding layer in G02, G02-8, shows planar lamination; the difference is only in the direction of water flow and location on the floodplain. There is some colour variation (yellows to olives) but this may have more to do with sediment content (there was also variation in colour between the mud/sand laminae). The regular alluviation is interrupted in the terrace trench by two small layers consisting of coarser and darker sediments (T01-8 and 10). There may be a corresponding layer in G02 (G02-6). It would seem that the river's stream power increased temporarily at this point (i.e., flash flooding).

This regular alluviation and later flash flooding would have made settlement on the (wet) floodplain difficult. However, at some point some settlement was possible, albeit on a higher elevation. During the Neolithic, there was a settlement about half a kilometre west of Hirbemerdon Tepe, located on part of the Pleistocene terrace (T3). Unfortunately, the dating of this site is imprecise, however, it may broadly correspond to the period of incision in the Late Neolithic found in Doğan's research area (Doğan 2005a).

There was also a Chalcolithic settlement (first half of the 4th millennium) on the floodplain, overlain by a flood deposit (possibly T01-10 or 8) (Laneri *et al.* 2007; 2008). The site was badly compromised by the flooding (Laneri *et al.* 2008) but the presence of mudbrick indicates that this was a permanent settlement, rather than a seasonal camp. This suggests that the floodplain must have experienced some sort of break in alluviation/aggradation (with corresponding river incision), and this may have occurred when layer T01-11 and G02-8 had been deposited. This may correspond to the incision period in the late Chalcolithic in Doğan's area, although there seems to be little evidence of permanent settlement in the floodplain (Doğan 2005a).

There is no evidence to suggest whether or not habitation was continuous from the Neolithic into the Chalcolithic in this region. T01-11 may have indications of soil formation processes in terms of a slightly elevated magnetic susceptibility reading (see Appendix E).

This cycle of deposition (although with a possible incision break) seems to correspond with Doğan's cycle II deposits, which he believes date to the end of Chalcolithic, based on the dates of settlements on top of this layer (Doğan 2005a).

The evidence at Kazane Höyük argues in favour of wetter conditions prevailing at the time: gleyed clays and regular alluviation (Rosen 1997). This was followed by a period of channel erosion at the end of the third millennium (Rosen 1997), discussed in the next section. The evidence from Titriş Höyük also seems to indicate wetter conditions at this time (Algaze *et al.* 1995). At Hirbemerdon Tepe, the period of wetter conditions is followed by probable channel incision and flash flooding, i.e., a drier phase. This broadly correlates with the proxy evidence from Lake Van where there are wet-dry fluctuations at this time (see Roberts *et al.* 2011b).

Late Mid-Holocene to early Late Holocene (EBA through MBA)

Between 3000-2000BC, at various parts of the Bismil-Batman section of the Tigris, there is evidence of 'flooding' (Doğan 2005a), perhaps indicative of a drier regime. Flash flooding occurs in more arid regimes. When there is rain, the water surges through the channel, picking up sediments along the way. In addition, more sediments may be washed in from the slopes (there may be less vegetation and so there is increased erosion of sediments), increasing the sediment load of the river. These are then deposited further downstream as poorly sorted deposits.

At Aşaği Salat, there is renewed alluviation circa 2650 BC, but later flash flooding occurs throughout until the Iron Age, and no settlement occurs there (Doğan 2005a). Doğan's descriptions, while there are superficial similarities to the sediments at Hirbemerdon Tepe, seem a bit vague. There is no separation in deposition episodes between the EBA into the Iron Age, however, the sedimentary evidence at Hirbemerdon Tepe indicates that there seem to be different episodes which should be highlighted.

At Kazane Höyük (Rosen 1997), in the Urfa plain, as well as at Titriş Höyük (Algaze *et al.* 1995), the sedimentary record indicates that there is increasing aridity and erosion. However, at Titriş Höyük, the record is a little less clear and the role of human impact (in terms of decreasing vegetation) in the flash flooding is unknown (Algaze *et al.* 1995).

The evidence at Hirbemerdon Tepe seems to agree with the conclusions reached by Roberts *et al.* (2011a), who stated that there were wet and dry fluctuations from the end of the third millennium going in to the second. This is indicated by the sedimentary record as well as the phytolith evidence. In the terrace trench, layer T01-7 underlies the later EBA T01-6 (dating of which will discussed below), and could have been deposited at any time between the Chalcolithic and EBA (but most likely early EBA – see below). This layer may coincide with Doğan's aggradation layers at Aşaği Salat post-2650BC. Sedimentary analysis was carried out on this layer, and two phytolith samples were analysed (sand layer (T01-7) and an above lying mud layer (T01-7a)).

The layer consisted of mainly massive very fine-grained sands, but with some lamination indicating more regular alluviation. It may be that this layer actually consists of various depositional episodes (flash flooding and regular alluviation) however, the breaks are not visible in section. In any case, the magnetic susceptibility and phosphate readings (see Appendix E) do not particularly stand out and thus there are no strong indications of soil formation or other activities in this layer.

The phytolith counts were very different (773 to 14,575/gramme) in the two samples with T01-7a (muds) containing the higher count than T01-7 (sands). This may be due to sediment type: phytoliths are more likely to move downwards in sandy sediments and settle in muddier layers (see Chapter 5). In both samples, the evidence indicates that there was an even mix of C_3 and C_4 plants and perhaps less water availability (as compared to the later T06 layer; see Table 6.1). The D/P ratios also varied, with T01-7a having a higher presence of dicotyledons than T01-7. This may, of course, have to do with phytolith counts biasing results. This layer had the highest number of phytoliths in the terrace trench (see Chapter 6 and Appendix H for relevant histograms), and since dicotyledons produce far fewer phytoliths, the dicotyledon count for T01-7 may not be fully representative of what was there (i.e., there may have been more trees and shrubs than indicated). In any case, both samples show that trees and shrubs were in the vicinity (and in similar percentages) perhaps reflecting riparian vegetation.

The phytoliths in T01-7 were heavily weathered, likely through dissolution so it is possible that many dissolved completely or to the extent of being unidentifiable. It is also possible that these were deposited *in situ*, rather than transported here from elsewhere as there appears to be little fracturing or hollowing out. The phytoliths in T01-7a were much less dissolved and although some were fractured (indicating transport of some of the phytoliths), it could be that this sample represents a land surface. However, the soil formation processes must have been nascent and there must have been rapid burial, otherwise there would have been more dissolution.

T01-7 was dominated by wetland plants and dicotyledons, T01-7a had many more grasses, but no cultivated species were identified. The PCA analysis also indicates that T01-7a was very different to T01-7, indicating that there was a change in vegetation. Charcoal was also found in the sample, so it is possible that this area was cleared (slash and burn), perhaps for farming or for grazing, and may be associated with the EBI or EBII settlement at Hirbemerdon Tepe. There were also a few jigsaws in T01-7a, indicating most likely wetter forest conditions. It is also possible that this area was partially waterlogged: diatoms and sponge spicules were present in the sample.

In the second terrace section, layer G02-4 seems to broadly correspond with T01-7, G02-3 may be correlated with T01-6. G02-4 may represent an area of the floodplain overbank / levee deposits, and the deposit is thicker than T01-7. Again there are some laminations, i.e., fine sands with laminations of granules and muds. Although the overall grain size is smaller in G02-4 (see Appendix D), the granule laminations may be indicative of slightly higher magnitude flash flooding episodes, showing that there may have been slightly more floodplain instability during this period, not instability caused by predictable seasonal flooding (which can be easily mitigated against), but unpredictable flooding.

The magnetic susceptibility and LOI readings were low, phosphate was slightly higher (see Appendix E). None of this firmly indicates soil formation, at least where this layer was sampled. The phytolith data does not help too much as well, because the count is very low. It seems that there are far fewer dicotyledons, though this could be a reflection of the total number of phytoliths (dicotyledons produce much fewer phytoliths). The D/P ration was low, however. There was no data for aridity (divisible by zero error), the C_3 / C_4 ratio is similar to that of T01-7 (see Table 6.1). There is a little less water availability; the difference is minimal. It could, tentatively, indicate a slightly drier phase. Non-identifiable grasses dominate, and it could be there was grass (possible agriculture) coverage in this part of the floodplain, although there were some wetland plants as well.

G02-3, which lies on top of G02-4, is composed mainly of muds (silts with some clays: see Appendix D) with a massive structure. There was no evidence of regular alluviation. There was a slightly higher magnetic susceptibility reading as well as LOI reading (see Appendix E), so there was some nascent soil formation.

The phytolith count was a little higher, though still not making the index results particularly robust. Again, aridity could not be calculated, however, the dicotyledon count again seemed a little low, like in G02-4 and the D/P ratio is again low. The C_3 to C_4 ratio is similar to the layer below and there seems to be slightly more water available, perhaps this represents a slightly wetter period. The phytoliths were also quite dissolved but with little fracturing, so there could be *in situ* deposition and dissolution, due to perhaps soil formation processes. It should be noted, however, that phytoliths will not be able to move down the profile in more clayey substrata (as opposed to more sandy sediments) and so this also could account for the slightly higher phytolith count.

There was also charcoal present in the sample, indicating possible agricultural or other human activity in the vicinity. This area was dominated by grasses (as identified through multicells), including *Aegilops* sp., which is an agricultural weed, thus supporting the idea that there was agricultural activity in the area. The low D/P value could also be a sign of earlier clearance for farming. Bromus was also identified, as well as possible *Juncus* sp. Interestingly, there were also possible fruit phytoliths (decorated polyhedrals), perhaps indicating fruit trees in the vicinity. This could be a very important feature as it could provide a *terminus post quem* date for this layer. Fruit horticulture and the domestication of fruit trees, came much after the domestication of cereal crops, likely around the Chalcolithic period (Zohary *et al.* 2012). As such, this layer may have have formed sometime during or after the Chalcolithic, probably around the time of the EBI settlement at Hirbemerdon Tepe.

The contemporaneous trench layer T01-6 was very interesting and an anomaly; it also stands out as an outlier in the PCA analysis. It is a layer that consists mainly of muds, with some sand laminae (see Figure 7.2). The phosphate, LOI and magnetic susceptibility readings are all low (see Appendix E), indicating no soil formation processes.

The phytolith count is also low, thus making the various indices not very robust (no real data for aridity or tree cover). The C_3 / C_4 ratio was consistent, and there was high water availability. There were also some very large (100+ conjoined cells) multicells from emmer wheat (see Figure 7.3). What this indicates is that agriculture was occurring on this floodplain; there was also high water availability as indicated by the phytolith size (see Chapter 5 for further discussion), which is corroborated by the Fs index. As mentioned above, the PC analysis also indicates a change in vegetation patterns, ie a change to agriculture. There must have been soil formation in this layer (see discussion in Chapter 5) and it may be that the land surface was actually represented by a sand lamination and these phytoliths migrated down to the muddier laminae. The sediment sample may also have missed the actual land surface; the emmer wheat phytoliths were well preserved, and unlikely to have travelled far. This layer may date to the EBA.

The next layer to be deposited in the terrace trench section, T01-5, is composed of mainly massive fine sands, indicating that either stream power has

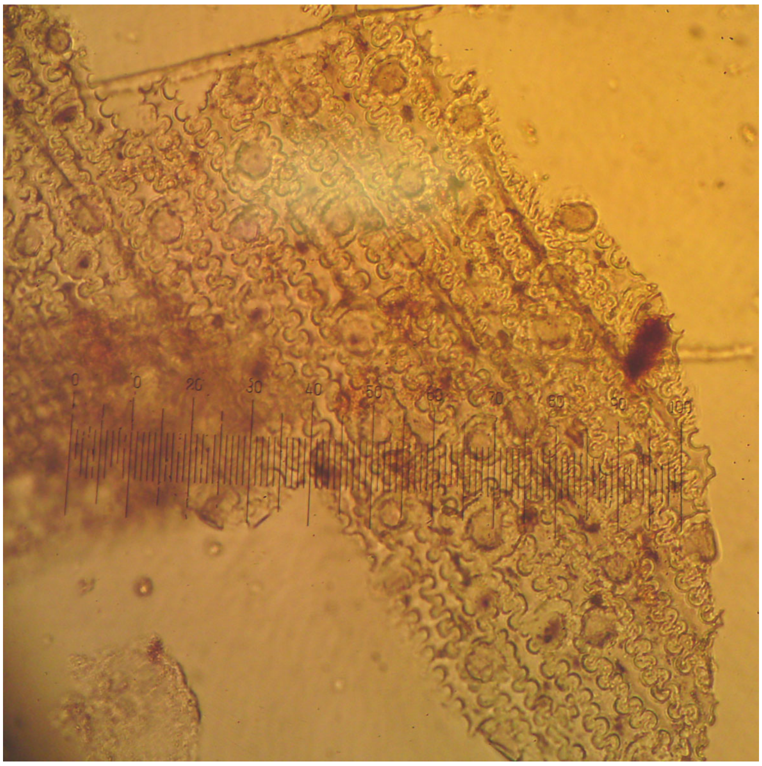

Figure 7.3: One of the large conjoined emmer wheat multicells found in T01-6. Scale is in micrometres

slightly increased or that the river channel has moved slightly. Muds were also present, and it may be that there was some lamination, obscured by later post depositional changes. Generally, these are typical floodplain deposits.

The LOI count is low, but there is a relative increase in the magnetic susceptibility and phosphate readings indicating that there may have been some nascent soil formation in this layer.

The phytolith count was still low, although somewhat higher that T01-6. The D/P ratio indicates tree coverage. However, other indices indicate that this may have been a period of slightly elevated aridity: the Iph is higher (though robustness of data is questionable) and the water stress index is also higher, in fact the highest of all of the indices for the offsite samples (see Table 6.1). There also appears to be an increase in the number of C_4 plants. The PC analysis also indicates variation in vegetation from what occurred previously. Aridity seems to be indicated, however, alluviation is still occurring. It may well be flash flooding (the sediments are very poorly sorted), rather than regular alluviation, or the laminae may have been affected post deposition. There is, however, an increase in wetland plants and they slightly dominate the assemblage. This deposit is interesting and could indicate a relatively drier period (a local reflection of the so-called 4.2KY event?). It could not have been very severe as the settlement at Hirbemerdon Tepe continued and even expanded; there is also possible evidence that cereal cultivation continued (cereal straw phytoliths were found).

G02-2 is composed of sandy silts and may be correlated with T01-5. No other analyses were carried out on this unit.

T01-4, G01-4 and G02-1 (see Figure 7.2) may all be somewhat contemporaneous layers. G02-1 is composed of muds and may reflect decreasing stream power or a slight shift in channel position (from proximal to distal). No other analyses were carried out on this sample but it is possible that it can be correlated with G01-4. T01-4 and G01-4 (although T01-4 may just predate G01-4) may be related. The phytolith evidence is similar, and this could be showing continuity of farming practices (see Chapter 8). It is also quite likely that these layers date to the MBA settlement period.

T01-4 is composed mainly of muds (silts and clays) with intercalations of sand, indicating possible regular alluviation. The decrease in grain size from T01-5 again indicates either a decrease in stream power or a minor shift in channel position or a decrease in flash flooding, more volatile conditions. In any case, these are still floodplain deposits.

The magnetic susceptibility and LOI readings are fairly low, however there is a high phosphate reading (see Appendix E), so there could be some soil formation. There is a slightly elevated phytolith count, so a land surface might tentatively be indicated. The D/P ratio shows that there were trees in the vicinity (similar to T01-5), the number of C_4 plants has declined, and the water stress has decreased somewhat.

Although the phytolith count was not very high, there are still some interesting aspects to this sample. There were some jigsaws indicating either channel irrigation or wetter conditions. There were also some fruit polyhedrals as well as a tentatively identified *Vitis* sp. epidermis (see Figure 7.4). It was difficult to identify this multicell, and the nearest identification seems to be *Vitis* sp., based on a reference image in Denham *et al.* (2012). If this identification is correct, it fits in nicely with the onsite data (see below) and could indicate that small scale

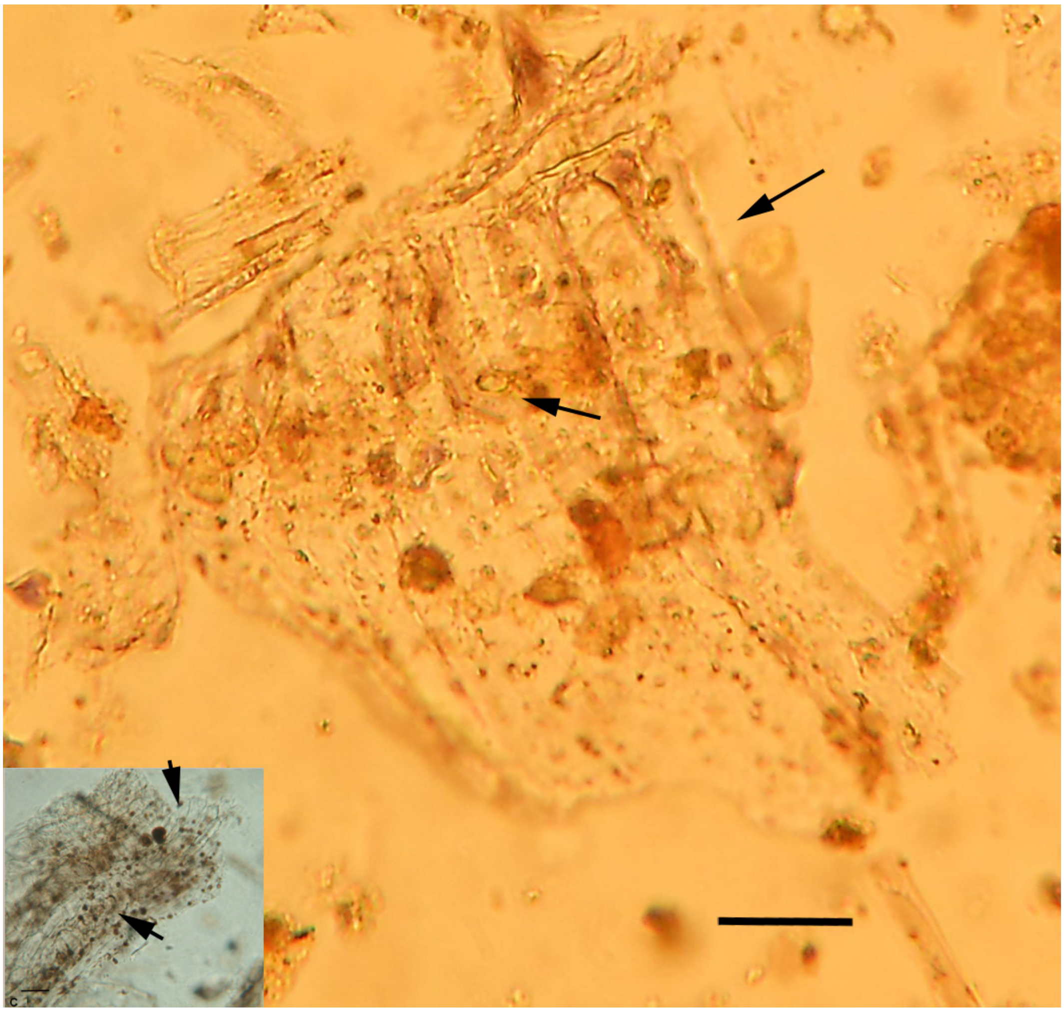

Figure 7.4: Tentatively identified grape epidermis. The identification was based on the similarity of irregular longcell walls, ill-defined blocky longcells and the papillae-like features (see arrows). They both also have dots scattered around, but these may be inclusions. Measurement bars in both images are 10 micrometres. Small image is from Denham *et al.* (2012)

irrigation was used in the vicinity (for the fruit). There were, however, no traces of cuts, channels or permanent canals in the sections. It is possible that since the river was still alluviating (i.e., regularly / seasonally flooding), there was no need for irrigation.

There were also some sponge spicules, and it is possible that this layer, which consisted of muds, was more waterlogged and some of the phytoliths moved down the profile from more sandy layers. Wetland plants do slightly dominate the assemblage and these may represent more *in situ* vegetation, the grasses may have been blown in from elsewhere, or moved down the profile. The higher phosphate reading could indicate that this was a land surface, albeit a more waterlogged one. PC analysis of this sample also bolsters the idea that there is a change in vegetation as there is again variation from the other samples.

G01-4 is comprised of mainly fine grained sands with a few inclusions (pebbles). The magnetic susceptibility reading was low, however, there was an increase in LOI and the phosphate reading was high, like T01-4, so again there is a possibility that a land surface(s) is indicated in this layer.

Two phytolith samples from G01-4 were analysed: one from the layer, G01-4a, the other from a thin layer that was burned and contained charcoal (G01-4c). The phytolith counts were very high in both, and indeed were comparable to the onsite samples. It is very likely that these two samples represent two different land surfaces. The Iph index (more robust this time) indicates some aridity, and is similar to T01-5. It is not possible to conclude anything about this data except to say that aridity was at a consistent level throughout the MBA period reflected in these layers. The D/P ratio for the burned layer was not possible, however, G01-4a indicated a low tree presence. This is different to T01-4 and could indicate that the riparian forest had been cleared for farming. It should be noted that the D/P ratio was also low in G02-4 and 3; this area may have been cleared earlier. The number of C_3 plants increases (though this may be a reflection of the agriculture being practised) and the water stress levels drop, and are similar (but even lower) to the possible land surface of T01-6, with the large multicells (although no large multicells were found in these samples, there are some in the onsite samples dating to this period, such as SC99-1). The overall evidence seems to indicate that this was a wetter period. Sands are also better draining and so better for agriculture.

G01-4a, which was taken above G01-4c, contained a very high number of phytoliths. Grasses dominate over wetland plants, and there are also possible trees and fruit indicated (see Appendix H and Chapter 6). Cereals, mainly unidentified husks (but some identified as *Triticum* sp.) were also present in the assemblage. Jigsaws, mainly as single cells, but with a few multicells, were also present, and the phosphate reading was high. What this possibly indicates is that there is a land surface, and agricultural strategies may also be gleaned. With the presence of both cereals and fruits, it is possible that polycropping was practised on the terrace. The jigsaws could indicate either irrigation or wetter forest conditions or indeed both. Fruit trees do usually require extra small-scale irrigation, however as the river was still alluviating, this may not have been necessary. Sponge spicules and diatoms were also present in this sample, probably washed in with alluvial deposits. As with T01-4, no sedimentary evidence of irrigation, i.e., channel cuts, was found in the section. Oak phytoliths may also have been identified. The combination of dicotyledon and oak phytoliths hints at an open woodland nearby, which could be corroborated by the presence of deer bone in the faunal evidence onsite (see below).

The phytolith count for G01-4c was the highest of all of these offsite samples and indicates a likely land surface. The types of phytoliths again hint at agricultural strategies. The sample itself consisted of burned vegetation (burnt phytoliths) and could indicate that field burning was a strategy. Agriculture and horticulture were both practised (unidentified cereals and possible fruit phytoliths), again indicating polycropping as a possible strategy. The legumes found onsite (see below) could also strengthen the argument for polycropping. Furthermore, as nitrogen fixers, legumes could be used to increase the fertility of the soil. There were also jigsaw single cells, most likely indicating wetter forest conditions nearby.

T01-3 is also probably MBA in date, however it was not analysed. It is composed of mainly massive fine grained sands with some cross-stratified sands; so it could be that the massive structures represents reworked sediments (post depositional change). The increase in grain size, from muds in T01-4 to sands in this layer could represent an increase in stream power or a shift in the position of the channel. These are floodplain deposits.

Early Late Holocene (post-MBA)

This period is represented in terrace edge section 1 (G01-3 and 2) and possibly in the trench section (T01-2 and 1). In the trench section, there seems to be some evidence of flooding occurring of greater energy (massive sands to granules), which may have led to the abandonment of the outer town, circa mid-2nd millennium BC (this date is based on the pseudo-Khabur ware assemblage found on the site which dates to 1815-1550BC: Laneri *et al.* 2007). This may be related (as a distal component) to the pinkish-orange flood layer (G01-2) found in the other terrace edge section. This layer was discussed above, but additional discussion is warranted here.

In Doğan's study area, he does mention a yellowish-orange flood layer at Aşaği Salat, which occurred some point after 2650 BC (2005a). If this is a flood layer from the same event, it may actually date to somewhere in the MBA (?mid-2nd millennium). In this section, the flood layer contained RBWW (red brown wash ware), which is ubiquitous in the region and used throughout the MBA, and possibly even Iron Age finds. These ceramic dates only provide a *terminus post quem*. The flooding may have occurred even later, and it may be that G01-2 and 1 reflect these later (?Byzantine) flooding episodes due to deforestation (AM Rosen, pers. comm.). According to the Van, Zeribar and Mirabad lake records, human impact on the woodlands is not apparent until the Late Holocene (Roberts *et al.* 2011b), with a decline in Quercus values circa 2100 years ago (Wick *et al.* 2003). As such, the flooding may not be related the abandonment of the the outer town.

T01-2 was analysed in the laboratory and although the phosphate and LOI readings were very low, the magnetic susceptibility was the highest of all samples. On the other hand, phosphate and LOI was higher for G01-3, but magnetic susceptibility was very low. It may be that these are reflecting two different flooding episodes or that they are both picking up on soils that got caught up in the flood events. T01-1 is composed of fine sands, with some cross-stratification, which seems to indicate that regular alluviation returned until river incision commenced once more and the formation of this terrace ceased. G01-2 is composed of muds, indicating that this is a more distal part of the floodplain and another possible shift in the channel. Magnetic susceptibility was low, but there was a moderately high readings for both LOI and phosphate, indicating that there might be some soil formation in this layer. This was then followed by incision of the river and the cessation of the formation of this terrace.

7.2.3 Discerning land and resource use from onsite phytolith data

As discussed in the Chapter 5, phytolith analysis can be used in a number of ways, for instance to understand processing and storage behaviours and crop use, which is often used to answer sociopolitical questions. These questions can include differentiating between the diets of the elite and common people, changing diets over time, understanding who has control over resources, to name a few. In this thesis, the onsite evidence, like the offsite evidence, will be used to try to understand what resources were available and used by the inhabitants and also to see if different agricultural strategies, i.e., modifying behaviours, can also be discerned from the onsite data and compared with the offsite data.

It is difficult to obtain detailed environmental information from onsite samples in any case, because for the most part the phytoliths will reflect cultural pathways. Most of the plants will have been brought intentionally – crops, building materials, etc – however, there will also be some unintentional guests such as agricultural weeds, which might give hints. The phytolith record from a site, however, does reflect what was available to exploit and what may have been grown in the vicinity (if not brought in by trade). In other words, how the land may have been used and managed.

The various indices (D/P ratio, Iph, Ic and Fs) were calculated for the onsite samples, however, they made no sense. This is because the types of phytoliths that will be found in onsite samples will be dependent on choice (i.e., what was chosen to be brought on site), room function (storage, processing?) and context (including building materials used). So, for instance, although the offsite samples (albeit not very robust) indicate that there was some tree coverage, the onsite samples indicate that there were few trees. This would be a reflection of building material choice (mudbrick was used, with timber roofing), rather than resource availability and vegetation. As such, this data will not be used, rather presence and percentages of phytolith types will be used, along with correlations, and of course, other datasets, including archaeology and macrobotanical and faunal remains.

This section, like the previous section will be divided into time periods, in this case: the EBA, MBA and LBA (post-MBA). Although there was settlement at Hirbemerdon Tepe in the Chacolithic period, in the outer town area, the excavation was only exploratory and no environmental samples were taken.

The Early Bronze Age

Unfortunately, very little analysis was undertaken for this time period, mainly because the more prominent MBA site overlies the EBA settlement and there wasn't the time to excavate further down to the EBA (the site was closed down in 2011).

Only two samples were taken from EBA contexts as discussed in the Chapter 6. These are a sample from an EBA floor (2277-2198 Cal BC, with associated DROB ware which dates to the post-Akkadian period) and another possible floor under this floor (see Figure 7.5). The phytolith counts were not particularly high, this is not surprising given that these were floor layers, which were probably swept clean by the inhabitants. The monocotyledon/dicotyledon ratios are similar to the later MBA samples and there were few multicells (see Appendix H). The numbers are very low and so it is difficult to come to any strong conclusions, but it does seem that shrubs/trees were likely used onsite, perhaps as building material and as charcoal. Although possible fruit phytoliths were identified in some of the offsite samples, none were found in these samples.

Some wetland plants were also detected in both samples as well as diatoms; these had a weak correlation (0.33): see Table 6.2) so likely they did not come into the record together. Only sedges were identified.

There may be a hint in terms of cereal cultivation at this time. Barley and wheat husks are present in SC-8, and there is a strong correlation between them (see Table 6.2), indicating that they came onto the site together; there is also a strong correlation between wheat, barley and wild grass. This is very interesting, because it may be that the barley husks are actually wild barley husks and have come in as agricultural weeds (see for discussion: Ryan 2009). In addition, no barley husks were identified in the offsite samples. What this could indicate is that only wheat, and quite probably emmer (the only husks found offsite in this period were identified as emmer), was being grown and consumed at this time. This is very tentative as the sample size is so small, of course.

Although the data is very limited, it does reflect that different resources were used, trees/shrubs and wetland plants, and that there was likely cultivation in the nearby area (confirmed by offsite data). This hints at a landscape with different possible microenvironments: woodlands, riparian forest, arable land and wetlands.

The Middle Bronze Age

The MBA levels were more extensively excavated and analysed that the EBA levels, and so this section will include not only the data from many more phytolith samples, but also data from macrobotanical remains and to a much lesser degree, animal bones. Phytolith samples were taken across the site and include contexts such as floors, street, ground stones, door sockets and tannours.

Resources used onsite can indicate the microenvironments (or niches) present in the environment, including arable, woodlands and wetlands. This section will discuss the findings in these groupings and will also include additional discussion on other activities, such as pastoralism and water management. This perhaps is the best way to glean information regarding the availability and use of various resources, and best leads into the next chapter, where cultural niche construction theory is discussed, using these niches.

The arable niche: crop plants and agricultural strategies

The evidence for this section comes mainly from the phytolith data, with some additional information from the charred macrobotanical material. The charred plant remains were flotted from sediment samples taken mainly from the architectural complex (the 'piazza' and Building G, with associated rooms: see Figure 7.5; Laneri *et al.* In press). It should be noted that there are no indications of storage from any of the micro or macro samples. Possible storerooms, in the series of rooms below the architectural complex, were found, for instance room 30 contained storage vessels (Laneri *et al.* In press; and see Figure 7.5). Unfortunately, these were excavated before I started on the project and were

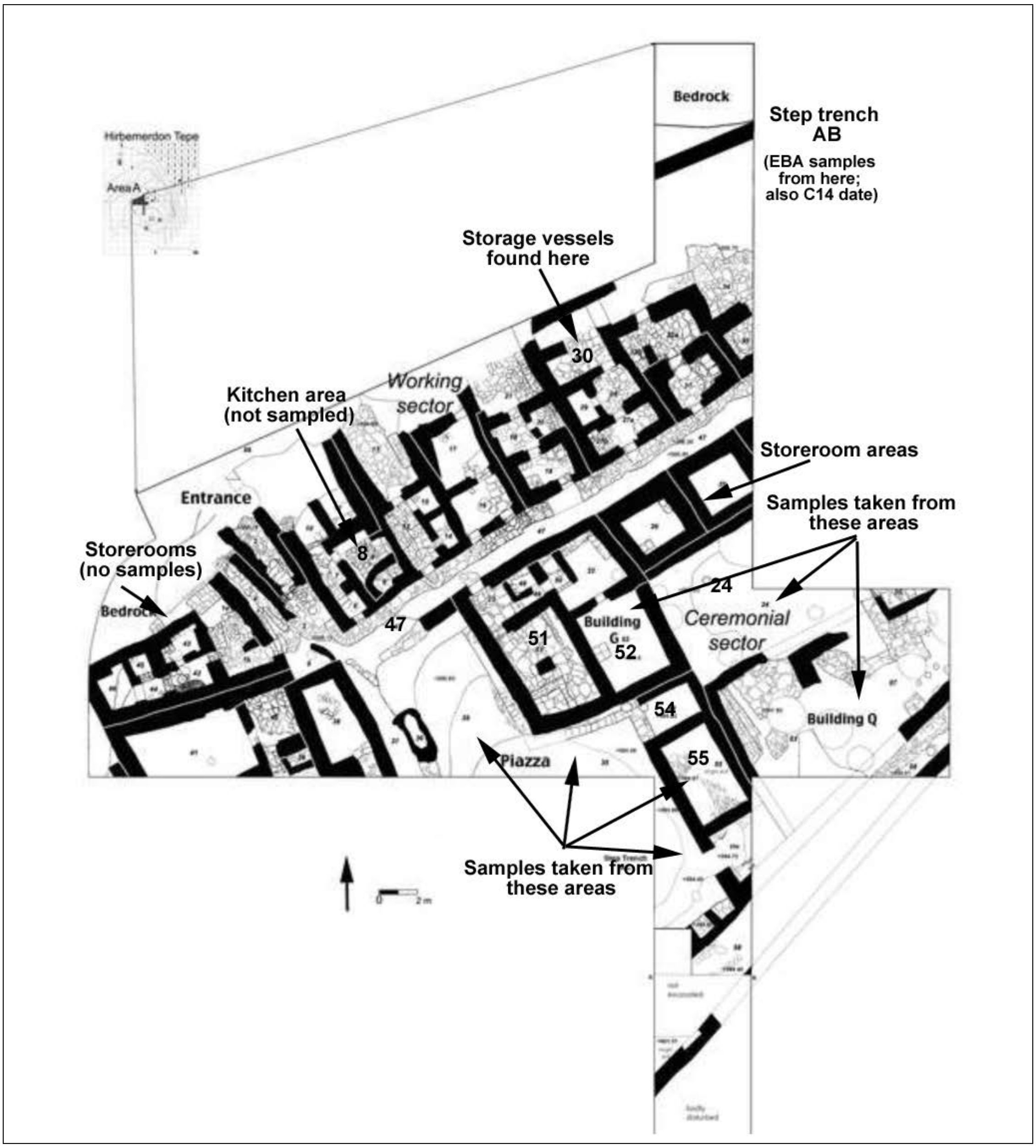

Figure 7.5: Plan of the MBA excavations, modified from Laneri *et al.* (In press)

not sampled. So although the full range of crops that were harvested/available to the inhabitants is obtainable, there is still a broad idea of crops grown.

The main crops preserved of course, are cereals. In the macrobotanical remains, both hulled barley (*Hordeum sativum*) and emmer wheat (*Triticum dicoccum*) are present. The phytolith evidence is similar, although, unfortunately, many of the husks were unidentifiable to genera level due to preservation issues and could only be categorised as 'cereal husk' (see Figure 6.13). Both barley and emmer wheat are more drought tolerant, but this may not necessarily be an indicator of environmental / climatic conditions as emmer was a preferred crop

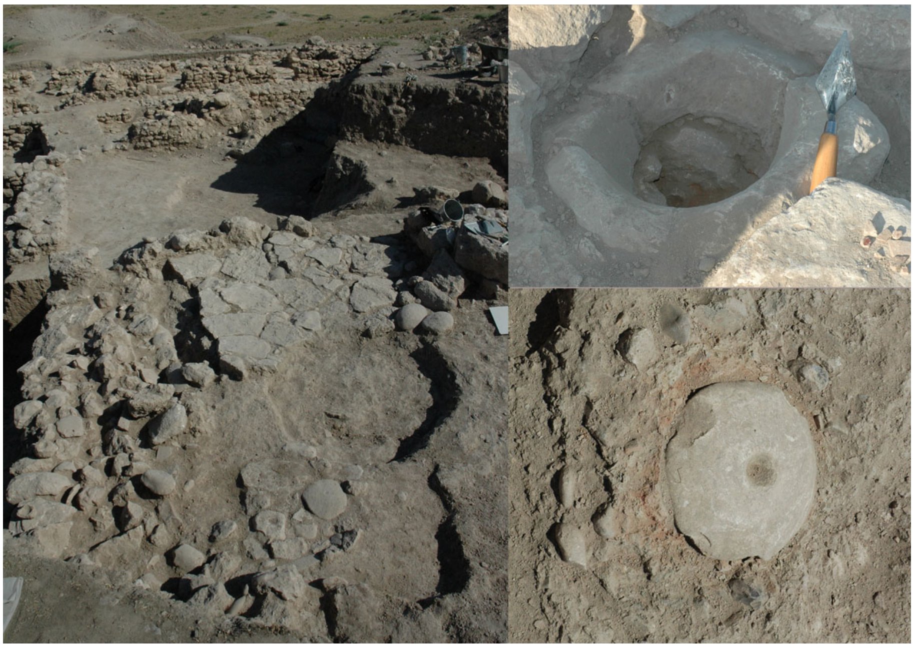

Figure 7.6: Photographs from Building Q, whose function is unknown but may have had something to do with ritual food preparation. Sample SC550-1 was taken from the flag floor, Samples SC624-1 to 3 were taken from the tannour (lower right), and Sample SC606-1 was taken from the probable door socket (upper right)

in this region at this time (Riehl 1997). However, the offsite evidence, specifically T01-5, may indicate that drought, or at least drier conditions, was an issue from time to time, and tentatively, as seen above, it may be that barley was not grown during parts of the EBA.

In any case, both emmer and barley were found in the architectural complex, as well as in Building Q (of unknown function, see Figure 7.5 and Figure 7.6), and in more domestic contexts. However, their correlations with cereal crops and each other, in different areas of the site are quite interesting. In the piazza area, where there was a peak in cereal husks (the burnt area of context 408, Sample SC518-2), there is a positive correlation between the wheat and barley (0.99: see Table 6.2). However, there is a lower correlation between weeds and both wheat and barley (-0.31 and -0.33, respectively) suggesting that these crops were quite 'clean' from weeds at this point.

There were some weeds of course, as indicated by both macro and micro remains and these included: goat grass (*Aegilops* sp.) and rye grass (*Lolium* sp.) in the phytolith assemblage, and bedstraw (*Gallium* sp.) and Medick (*Medicago* sp.) in the macrobotanical assemblage (Laneri *et al.* In press), all typical agricultural weeds. Other weeds may have also come in separately, more likely blown in, rather than purposefully brought in as fodder for instance, as this was a more ceremonial part of the site. In the domestic contexts (such as transect AC: see Figure 7.5), there was a high correlation between the barley and weeds, but no correlation between wheat and weeds. It is possible that the barley was being used as fodder, as well as foodstuff.

The cereal evidence does correspond to the offsite evidence to some degree. In the terrace edge samples (G01-4a and 4c), there was evidence that cereal was being grown on the terrace. The only husks that were identifiable to genera level were the wheat ones, but it is possible that barley was grown elsewhere on the terrace.

Other staple crops evidenced onsite included legumes, lentil (*Lens culinaris*) and grass pea (*Lathyrus sativus*) (Laneri *et al.* In press), but only as macrobotanical remains (these crops do not produce silica phytoliths). These are typical parts of diets at this time, but they also give us a glimpse into possible agricultural strategies. Legumes are nitrogen fixers and as such can be used to replenish the fertility of fields and can be used as an option to leaving fields fallow. It may be that crop rotation was practised in the fields on the terrace.

An interesting find, securely in the macrobotanical remains and possibly in the phytolith samples, is the grape (*Vitis vinifera*). Onsite, grapes seeds were found in the macrobotanical remains, possibly they were dried, used for making wine, or both. There is archaeological evidence from other sites in Turkey, including Titriş Höyük (Algaze *et al.* 2001) of possible wine making activity, and wine is mentioned as an export from Turkey in ancient sources (Soden 1994). A similar basin and drain to that at Titriş Höyük was found at Hirbemerdon Tepe in Room 27a-b (Laneri *et al.* In press). Given the proximity of this grape processing room to the piazza, it would seem that there may have been some sort of ritual context to the grape processing, and this keeps in line with evidence from other sites where there is ritual wine making.

Although no phytolith samples were taken from this particular room, samples from adjacent areas were taken, and in these there is some tantalising evidence for the presence of grapes, or at the very least some sort of fruit. In one room (52), which is located near room 48 where processing took place, possible epidermis multicell phytoliths from *Vitis* sp. were tentatively identified (see Figure 7.4 for image of possible offsite example). More epidermis multicells were seen in the basin deposit from the piazza, which indicates the presence of these fruit in this space, and on the pebble floor and one tannour in Building Q.

As mentioned above, the precise function of Building Q, which was poorly preserved, is not known, however, given the presence of the tannours, and its location in the monumental section of the site, it could have been some sort of cooking area for ritual / communal feasts. Grapes may have also been processed there (perhaps this is where they were dried?) and the waste from this could have been swept up and burned in the tannour(s). Another concentration of grape leaves was found in the ashy deposit from the street in Transect AC. This could indicate that grapes were also part of the everyday diet, in their fresh or dried form, and the waste products were burned in the street, along with the cereal husks (see above). There is also evidence of fruit, perhaps besides the grapes, in the phytolith record as reflected by the decorated polyhedrals. No other fruits were found in the macrobotanical remains, but this could be down to preservation issues.

This evidence also corresponds to the offsite phytolith record from T01-4, where there were possible grape epidermis and fruit phytoliths. If they are processing grapes onsite, it makes sense that they were also growing them on the terrace.

There does seem to be evidence of increased water availability at times, and it is likely that the inhabitants practised a mixture of (mainly) floodwater farming with rain-fed farming and possibly small scale irrigation, during drier periods. Large multicells (i.e., 10+ conjoined single cells) could be diagnostic of floodwater farming or channel irrigation, or more accurately, increased water availability. In these land surfaces, although multicells were present, there weren't any very large ones as found in T01-6. However, in one context onsite (Transect AC), there were some larger multicells present. In the offsite samples, and several onsite samples, jigsaw single cells (and in G01-4a jigsaw multicells) were identified. These phytoliths, as discussed above, form in leaves and have been found to form in greater numbers where there is more water available, either through wet forest conditions or channel irrigation (Tsartsidou *et al.* 2007).

Overall, the offsite and onsite evidence correspond nicely, and indicate a range of crops being used, as well as hinting a different agricultural strategies.

The wetlands niche

The evidence here is limited to the phytolith record as no macrobotanical remains were preserved. Wetland plants are ubiquitous in the phytolith record and do not seem to follow any temporal pattern (see Figure 6.15). There is no real contextual pattern either, as wetland plants seem to be in every context (piazza, tannours, floors, etc). They are particularly well preserved in the ashy deposits. Phytoliths do preserve well in ashy contexts but that aside, these phytoliths could represent waste material being thrown onto the hearths/tannours. In other contexts, such as the floors, wetland plants could have been used as matting/bedding (see Figure 7.15), baskets and/or roofing materials. Sedge is dominant, however, some phragmites and scirpus are also present.

The offsite evidence also indicates the ubiquitous presence of wetland plants. There may have been stands of sedges in parts of the river area, and / or marshy / waterlogged areas within the terrace itself. These may well have been managed in order to ensure a regular supply.

The animal bone assemblages (Laneri *et al.* In press) may also hint at wetlands management, with the presence of cattle and pig (and wild boar). This will be discussed further in the next chapter.

The woodlands niche

As with the crop plants, there does not seem to be variation of dicotyledon phytoliths temporally onsite, although there might be some variation across contexts.

Outside of the tannour samples discussed below, there are other smaller peaks in the number of dicotyledon wood / bark samples (see Figure 6.14). These could derive from timber building material. Timber was found in room 52 (burnt roof beams). Dicotyledon leaves were also found in abundance outside of the tannour samples, it is difficult to ascertain the reason for their presence. Perhaps they are from plants used in some sort of medicinal / ritual function. There is also a peak in an ashy layer found in the piazza, which could be waste products from fruit and other foodstuff. These plants would have had many different purposes, including medicinal, ritual, foodstuff, decorative and so on.

The tannours are interesting as they indicate that both dung and charcoal was used, and in the same tannours. Dung was also found in the macrobotanical samples (Laneri *et al.* In press). In the two tannours (Transect AC and Building Q), both charcoal and dung were used. Transect AC may be a domestic context, while Building Q may have had some sort of ritual food processing function, given its proximity to the piazza and the number of tannours and hearths. In the 'domestic' tannour, very little phytolith evidence for charcoal was found as compared to the ritual one. Dung was more used in this tannour as well as the hearths in Building Q.

Dung and charcoal burn differently and so can be used to cook different foods. As both fuel types are present, it is unlikely that fuel decision-making was based on environmental concerns (it has been argued that increasing dung usage may be an indicator of deteriorating environmental conditions: Miller 1990). It is more likely that charcoal was reserved for specific uses (mainly ritual) and the use of charcoal may have been controlled by the religious and/or political authorities (see below). In all of the tannours and hearths, the predominant dicotyledon phytoliths are from leaves, which brings up an interesting clue regarding pastoral and dung use practices. This will be discussed more fully below.

Red deer bones were found in street 47 (area between the domestic and ritual sectors) and the piazza. Red deer prefer an open woodland habitat and can be maintained. As will be discussed more fully in the next chapter, deer were central to the cult at Hirbemerdon Tepe and thus central to its ritual economy. As such the woodland habitat has to be maintained in order to preserve deer stocks.

The offsite samples also contained evidence of nearby shrubs /trees as well as hints of woodlands in the regional area. There may have been areas of riparian forests, and more likely, woodlands in the uplands. There were also possible oak phytoliths, again hinting at open woodlands. The use of timber on the site indicates that trees were in the vicinity, although these could have been transported in but this maybe is less likely for a rural site.

Pastoralism

The animal bone assemblage indicates that there was indeed pastoralism being practised as part of the site economy, with the presence of both sheep and goat. Sheep and goat herding is a common economic strategy and so comes as no surprise. However, the phytolith evidence may shed some additional light on what type of dung was being used. In all of the tannours and hearths, the predominant phytoliths are from dicotyledon leaves and with the exception of the Building Q tannour, there are very few, if any, phytoliths from cereal/wild grass straw. It seems that if the dicotyledon leaves are from dung, then possibly the dung used may be primarily from goat rather than sheep, since sheep normally eat grasses. This could also indicate that goat was more important to the economy than sheep, and that it may have been the inhabitants of Hirbemerdon Tepe who were keeping the goats. Of the actual identified goat and sheep bones from the site, goats do somewhat dominate (Laneri *et al.* In press).

It is difficult to ascertain who actually owned the herds: individuals or groups from the community or were there pastoralists that traded with the community? The fact that dung fuel was used indicates that there was probably a local herd that provided readily available fuel that could be used straight away or stored for later usage.

Water management

On site, water management is key. As people need water to drink and to make certain foods and drinks (wine perhaps in this case, see below), provision for water is important. Water may have been procured from the nearby Tigris and the adjacent wadi. The Tigris water now is undrinkable due to pollutants and is very sediment heavy. With the given evidence, it is not possible to determine how fresh the water was during the MBA or indeed if the Tigris was used as a source for drinking water. However, there would have been periods where the sediment load was heavy (evidenced by the alluviation) thus rendering the water undrinkable. The wadi may have provided some water, and there may have been springs (in the karstic landscape) that would more likely have been exploited. These external water sources can only be guessed at.

No evidence of water storage containers was found. However, there is evidence of onsite water management: drains which could have carried rainwater and snow melt were found across the MBA site. These drains would have had two functions. Firstly, they would have diverted water away from the houses and buildings. As this site was built into a slope, any water would have flowed downhill, collecting at the bottom of the site. This could have cause problems with damage to mudbrick buildings and localised flooding. The diversion of water to other areas would have mitigated the effects of this.

In addition, some of the drains emptied into semi-circular basins located in two streets (47 and 67: see Figure 7.5, street 67 is south of the Piazza, but not shown on this map), which could have been used to store drinking water for human and/or animal consumption (Laneri *et al.* In press). There is also evidence that these drains had a role in grape processing, perhaps even wine making (Laneri *et al.* In press); similar features were also found in Titriş Höyük (Algaze *et al.* 2001). The basins may have played a role in certain rituals in the Piazza (Laneri *et al.* In press).

Diatoms were found in many contexts across the site, in fairly high numbers. In addition, despite the strong presence of wetland plants, there is a low correlation between diatoms and wetland plants. This suggests that they did not come into the archaeological record together, which would be expected when there is a low number of diatoms (brown algae tends to grow on rocks and plants and adheres to plants as they are removed from their original habitat and brought onsite). Some of the diatoms may have entered the record this way, and others through the presence of mudbrick, but these pathways cannot account for the peaks that are found in some contexts. It is more likely that the brown algae (and hence the diatoms) formed in the drains found on the site (thus helping to confirm the function of these features). In room 52, possible fern phytoliths were also found, which may have grown in cracks near or in the drain itself.

Post MBA

The post-MBA period samples come from fill layers and thus context/function is difficult to ascertain. Instead, only general trends can be hinted at (see Chapter 6 and Appendix H for relevant histograms). Wetland plants are still ubiquitous, with some phragmites still evidenced. There are also cereals and dicotyledons present, but no possible fruit phytoliths were seen. There seems to be some farming but not all of the previous crops are represented. The offsite samples indicate flooding, but when this occurred in relation to the post-MBA settlement is unknown.

7.3 Bakr Awa and the Sharizor plain

7.3.1 The hydrological and vegetation history of the Shahrizor plain

Introduction

Unlike the survey of the environs of Hirbemerdon Tepe, which encompassed the immediate area around the site, the geaoarchaeological survey of the Shahrizor extends from Suleimaniya in the north of the plain to Halabja in the south (see Figure 3.15). It forms part of a larger project which includes a historical geographical survey project (directed by Professor Karen Radner of UCL), a site survey project (directed by Dr Simone Mühl of University of Munich), a palaeoecological survey (directed by Dr Mark Altaweel of the Institute of Archaeology, UCL) and several site excavations, including Bakr Awa (directed by Dr Peter Miglus of Heidlberg University).

There have been several seasons of geoarchaeological survey, including the initial survey of the plain (undertaken by Dr Altaweel and myself in 2011), two seasons of coring (undertaken by Dr Rob Homsher and Professor Arlene Rosen with Dr Altaweel in 2012), and further seasons in 2013 and 2014, where several trenches were recorded (undertaken by Dr Altaweel, myself and several other team members). The discussion presented here is based mainly on the initial season, particularly on the section drawings from large trench excavated near Bakr Awa, sediment descriptions and phytolith samples taken from this trench and Bakr Awa itself. There will also be reference to the other trenches excavated in 2013, and comments regarding the cores from 2012. Phytolith samples were taken from several different trenches in the region as well as the site of Bakr Awa. The offsite samples come mainly from the deep trench near Bakr Awa. Three other phytolith samples come from a river terrace near Yasin Tepe, but cannot be correlated to the Bakr Awa trench so will only be briefly discussed in this section (see Chapters 6 and 7 for more details). The other samples were collected very recently and so time constraints did not allow for their analysis. It is is hoped that these samples and cores will be analysed shortly and compared to the results at Bakr Awa.

This chapter will be divided by geographical region: Bakr Awa to Gurga Chiya, Yasin Tepe and environs and Bagum to Shamlu (see Figure 3.24). There will first be a discussion on the sedimentary sequences and available offsite phytolith analyses across the region, followed by a discussion of the onsite phytolith evidence. This will then be followed by a discussion tying the different strands of evidence in order to try to elucidate vegetation/climate and land use changes.

The sedimentary evidence

Bakr Awa to Gurga Chiya transect

In the region between Bakr Awa and Gurga Chiya, located south of the Darband-i khan dam lake, a very large trench was excavated (the deep trench), and a series of seven cores (C1-7) was taken across a transect between the two sites, and in a cluster near well cut G24 (see Figure 6.21). The deep trench, measuring 40 x 20 x 6 metres was excavated in the terrace area between Bakr Awa and Gurga Chiya. It was drawn, photographed and sampled for phytolith analysis.

In the results chapter, the two main sections (east and west) were described separately (see Figure 6.17 and Figure 6.19). Here they will be discussed together, with the phytolith data, to try to piece together the depositional and vegetation history. 18 samples were analysed from the deep trench.

As discussed in Chapter 6, a Pleistocene gravel layer was reached at about 6 metres down (this was further excavated another metre down). There was a sharp erosional boundary on top of this gravel base overlain by mainly silty clays and gravel lenses and cuts. At about 5 metres down, a sherd of badly preserved pottery was found, and an Achaemenid period sherd was found at about 1.5 metres down. This latter sherd was found below a gravel cut and soil horizon above it, and so provides a *terminus post quem* date of about 2300BP. The sediments between this sherd and the erosional boundary therefore represents most of the Holocene from about 12,000 BP to about 2300BP (*circa* 10,000 to 300BC). However, more tentative dates, derived from phytolith analysis, have also been obtained (see below).

Generally speaking, the phytolith count and silica content was very low across the samples, and lower than at Hirbemerdon Tepe. This unfortunately, affects the robustness of the data. The relative lack of phytolith evidence can be partly anyway, explained by the taphonomic processes discussed in Chapter 5, as well as the very active channel cutting, i.e., erosion of sediments, that occurred, particularly in the Bakr Awa area as will be discussed below. The only exception was Sample P023, which had an abundance of over 12,000,000.

There were also few multicells, but again this is not surprising given the state of preservation of the phytoliths as a whole. When P023 is removed, there appears to be another peak of phytoliths for OST1-2. This is also the layer that contains three outliers in the PC analysis (PO26, P025 and P024), indicating that there is more variation in vegetation during this period. In this layer, the total phytolith counts were slightly higher than in OST1-1 and OST1-3, however, the numbers are still very low and so interpretation is more possibility than probability.

The different indices (tree cover, aridity, climate and water stress) were calculated on these samples, however, the results were problematic in that there was too much variation in the same deposits. This is most likely due to the low phytolith abundance in most of the samples. As such, these results will be used very tentatively.

Overall, these sections indicate an area of frequent channel cutting and erosion, followed by deposition of fine grained sediment. There also appear to be multiple channels, which were simultaneously active. There was no stratification apparent in the layers, so it could not be determined whether sediments were laid down in one event, or multiple events. They will be treated, particularly when discussing the phytolith evidence, as deposits (i.e., OST1-1 deposit), but this does not necessarily mean that there were not multiple depositional events.

The sediment overlying the gravel base on both sides of the trench consisted of very clayey sediment (OST1-1; see Figure 6.17 and Figure 6.19), and was dark reddish brown (7.5YR 3/4 dark reddish brown). The sediment was wet and heavy. On the west side of the trench, in the OST1-1 layer, there is an area of mottling (red and grey), indicating a redox effect. As mentioned below, because of the channel cutting and erosion of sediments, much of the data (microfossils contained within those sediments) will have been lost and as such, there won't be a continuous record of vegetation. However, we may be able to obtain hints of vegetation and resource availability.

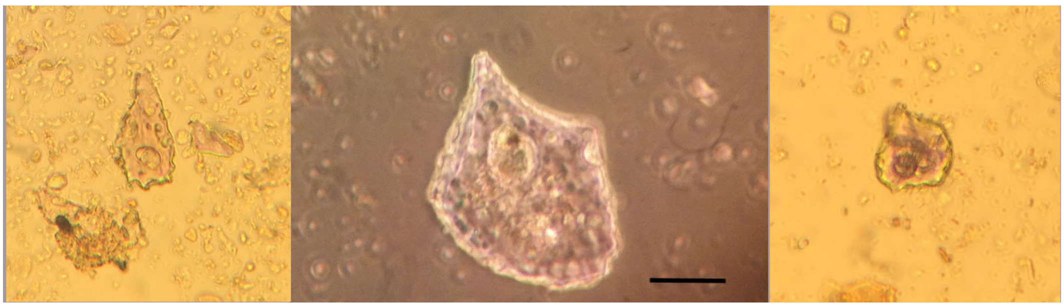

Figure 7.7: Dissolved and fractured phytoliths from offsite samples. Heavily pitted unidentified phytolith showing both dissolution and impact marks from transport (left); heavily weathered keystone, again showing dissolution and impact marks (centre); heavily weathered ?keystone, with dissolution and impact marks (right)

The phytolith abundance was very low, there was some charcoal in the sediment, and possibly burnt phytoliths. Many of the phytoliths, particularly monocotyledons, were badly preserved, with heavy dissolution and fracturing (see Figure 7.7). However, some of the phytoliths, especially sedge cones and dicotyledons appeared to better preserved. It is possible, as was discussed in Chapter 5, that the less preserved, more fractured phytoliths were transported

Sample no.	Depth (metres)	Section	Layer	Relative date	Comments
Bakr Awa					
P021	5.4	west	OST1-1	Early Holocene	Pleistocene base
P004	5.1	east	OST1-1		
P020	5	west	OST1-1		
P003	4.9	east	OST1-1		
P014	5.2	west	OST1-1a	?Neolithic	Grain cultivation
P013	4.9	west	OST1-1a		
P012	4.6	west	OST1-2	?Pottery Neo	pottery
P002	4.5	east	OST1-2		
P026	3.8	west	OST1-2	?EBA (ED I)	?fruit cultivation
P025	3	west	OST1-2		
P010	2.7	east	OST1-2		
P024	2.5	west	OST1-2		
P009	2	east	OST1-2		
P019	4.5	west	OST1-3		
P011	4.3	west	OST1-3		
P018	4.2	west	OST1-3		
P001	3.4	east	OST1-3		
P023	1.8	west	OST1-5	?Achaemenid	Pottery
Yasin Tepe					
P045	1.4				
P043	1.25				
P042	1.05				

Table 7.1: Possible dates for the offsite deposits, based on pottery and phytolith evidence

from elsewhere, and the sedge and dicotyledon phytoliths represent *in situ* deposits, i.e., a riparian type forest in this area. The wetland and dicotyledon phytoliths also somewhat dominate the record, and are weakly correlated according to the PC analysis, again suggesting a riparian environment (see Figure 6.29). There are also more multicells preserved in this deposit and some sponge spicules, which reflect a watery environment. There doesn't appear to be much difference between the mottled area (OST1-1a) and the rest of the deposit, except for an increase in sponge spicules (samples P013 and 14) and the presence of diatoms in one of the samples (P013, see Appendix J). The mottling and presence of diatoms and sponge spicules suggests that this area fluctuated between wet and dry.

One of the OST1-1a samples contained the only grass multicells. The PC analysis also indicates that this sample differs from the others, however, the grasses may have blown in from a nearby grassy area. Some of these were cereals (either wheat or barley). This indicates cultivation in the area and gives this part of the deposit a possible *terminus post quem* date in the Neolithic (see Table 7.1).

There were also fibre-type microfossils, which are yet to be identified (see Figure 6.28). They may be some sort of wetland plant.

Above this, on both sides of the trench, there is deposit OST1-2. It is somewhat more silty and browner in colour and may represent floodplain deposits, indicating through increasing grain size, a change in channel position. The phytolith abundance is appreciably higher, although still low in actual numbers. There are also more multicells in this deposit, again indicating somewhat better preservation (see Appendix J).

Sponge spicules and/or diatoms are present in most of the samples from this deposit, and in higher numbers. Again, preservation plays a role, but this also indicates the continued bogginess of the environment. In some of the samples, such as P002, the spicules were very large (see Figure 6.27). There were also very large examples of the unidentified fibre type microfossils. Generally, the dicotyledon and sedge phytoliths were less dissolved and fractured than the grass phytoliths, which could mean more *in situ* deposition and thus a wetland environment. The grasses could have travelled downstream or been blown in.

Charcoal was present in most samples, perhaps indicating some sort of anthropogenic activity nearby. Some cereal multicells were identified in sample P025 (see Figure 6.30), including wheat, thus agriculture was practised somewhere in the vicinity. This sample was also an outlier in the PCA plot, which supports the idea that something different was occurring at this point. The charcoal detected in the samples could be the result of field burning, either between sowings or to clear land of trees and shrubs. Burning of fields is more indicated as some of the multicells appeared to be burned. The presence of the poorly preserved sherd found in the same deposit, but slightly lower at about 4.6 metres down, helps to give a possible *terminus post quem* of the Pottery Neolithic for this lower part of the OST1-2 deposit.

However, there is also the presence of possible fruit phytoliths, i.e., fruit trees in the vicinity, in the upper portion of OST1-2 (about 3.8 metres, in Sample P026; see Figure 6.30 and Table 7.1). P026 is also another outlier in the PC analysis. Because the earliest evidence for fruit horticulture dates to the Chalcolithic (Zohary *et al.* 2012), this part of the layer most likely dates to this period or later. The question is if the fruit horticulture in this deposit is related to the Chalcolithic site of Gurga Chiya or the later site at Bakr Awa (although there may have been late Chalcolithic settlement at Bakr Awa: Miglus *et al.* (2013)). Possible fruit phytoliths were found in the early ED / Akkadian contexts at Bakr Awa.

There were also jigsaws throughout this deposit (in samples P026, P010, P024 and especially P025; see Appendix J), which, as discussed above can indicate wetter forest conditions or channel irrigation. One sample (P025) contained slightly more phytoliths and so perhaps the indices results may be more robust. The D/P index (tree coverage) indicates that there were trees in the vicinity (based on the criteria set by Delhon *et al.* (2003)). The aridity index is not valid (divide by 0 error) due to lack of relevant phytolith morphotypes. The climate index (C_3 to C_4 ratio) indicates that the ratio is equal. Finally, the water stress levels are low. Overall, the phytolith evidence (although minimal) seems to indicate the continuing presence of a wet riparian environment with agriculture nearby. However, the PC analysis also indicates that this period was more variable in terms of vegetation, which could be the result of the horticulture and agriculture being practiced: P024, 25 and 26 are all outliers, indicating variation. So although there was some continuity in terms of a general riparian environment, changes in vegetation patterns were occurring and can be seen in the relationship between variables in the PCA graphs.

Above OST1-2, there is a channel cut, which is more pronounced on the east side of the trench (see Figure 6.17 and Figure 6.20). Because of the way the gravels are imbricated, it is possible to see that the channel flowed northerly, towards the modern dam lake. This is, of course, logical as it is following the path of least resistance, flowing from the mountains to the lowest point of the confluence of three rivers.

This gravel layer is overlain by OST1-3, which is the same colour as the sediment below (7.5YR 4/4, brown) and also contains calcium nodules. There is also mottling in this layer on the east side. OST1-3a overlies OST1-3 on the west side, and differs only in terms of the lack of calcium nodules. Both OST1-3 and 3a have been interpreted as channel deposits. There is no proper fining up sequence as would be ideally expected. It is possible that this channel represents a flooding (secondary) channel or cut off chute that filled up quickly (see Brown 1997).

Four phytolith samples were taken from deposit OST1-3, and again all indicate the continuation of a wetlands type environment with possible anthropogenic activity (i.e., agriculture) taking place nearby (see Figure 6.30). The continuity of the vegetation patterns is supported by the PC analysis which shows that samples from this deposit cluster together. There is also charcoal present in these samples as well as diatoms and sponge spicules. Unfortunately, overall phytolith preservation was very low, and very few multicells were preserved, so the usual caveat applies in terms of interpretations being considered as possibilities. In any case, the phytoliths are dominated by better preserved wetland plants and dicotyledons, with only one sample containing grass phytoliths (P019). There is, however, again possible evidence of fruit horticulture. Overall, OST-3 shows less variation in terms of vegetation change than the underlying OST-2 layer.

Around 2 metres down, there is a further channel cut, visible in both the east and west sections, as well as the north section (which was not cleaned or recorded: see Figure 7.8), which is overlain by a poorly sorted gravel and sand layer (OST1-4) on the east side, but not on the west side. A silty clay (5YR 4/3 reddish brown: OST1-5) layer overlies OST1-4 on the east side, and directly overlies the channel cut on the west side. The gravel imbrication indicates northerly flow towards the confluence. The gravel stratum is slightly thicker on the east side and could indicate the flow velocity was slightly stronger in that part of the channel (possible point bar deposits). This could also explain the OST1-4 layer. These deposits again likely represent a flooding/secondary channel or cut off chute deposits.

One phytolith sample (P023) was analysed from this deposit (OST1-5). This sample contained the highest abundance of phytoliths by far, with a number comparable to some onsite contexts. This sample comes from the same deposit

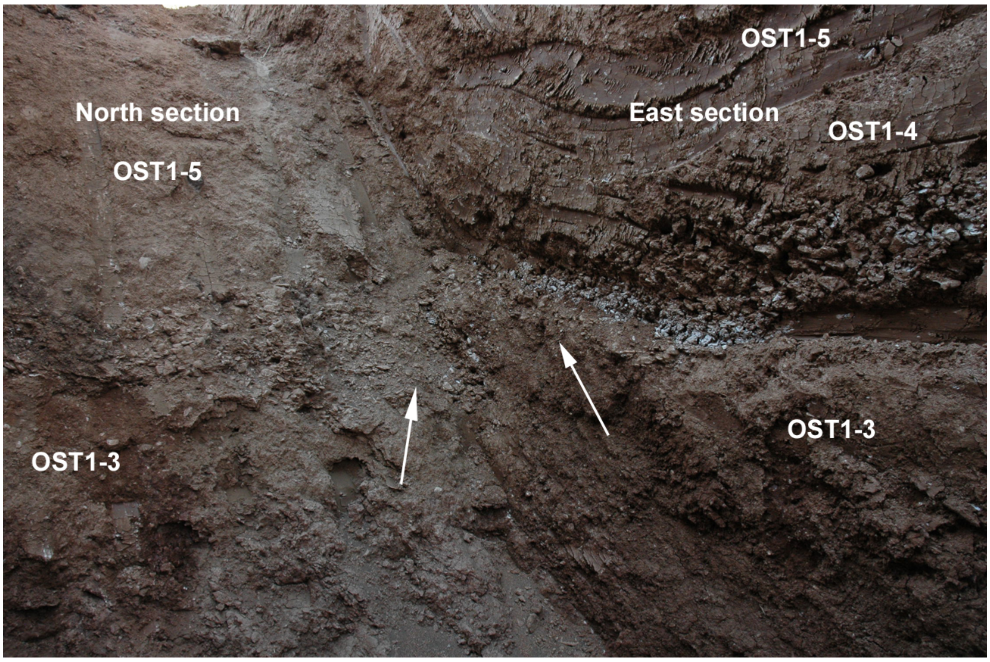

Figure 7.8: The north section (which is the direction of the Darband-i Khan dam lake) and the east section. Note the continuation of the gravel cut (arrows) across the sections: essentially this trench cut into the channel bed. Some of the deposits are also highlighted

as the Achemaenid period pottery and thus may date to around this time period. Above this layer is the modern soil horizon, measuring about 1 to 1.5 metres. The assemblage was dominated mainly by single cells (about 98 per cent) and contained the highest number of spicules and jigsaw phytoliths (see Appendix J).

It was also dominated by monocotyledons, and had a higher number of grass versus sedge (wetland plant) phytoliths (see Appendix J). However, it seems that the environment was still very much as it has been: a wetlands one. The grasses (all wild) were more dissolved and fractured than the dicotyledon and wetland plant phytoliths suggesting that these may have been transported from elsewhere, and that the trees/shrubs and wetland plants were more *in situ* and still dominated the immediate environment. This is further emphasised by the presence of spicules and jigsaw phytoliths. The indices, which are somewhat more robust given the much higher phytolith counts, indicate a similar pattern. Water stress is fairly low and there is ample tree coverage. The aridity index and climate index are a little more difficult to interpret as there is nothing really to compare against.

Above OST1-5 there is a 1 to 1.5 metre soil layer, made up of an A and B horizon. This soil began forming at some point after the Achemaenid period (circa 2300BP). The preliminary speleothem data, based on a Kuna Ba cave stalagmite recently analysed (Reuter *et al.* 2012) and dating from 500 to 2000AD indicates that there was a period of higher aridity circa 700 to 900 AD and 1100 to 1700AD. It may be at this point that this area became somewhat less waterlogged, hydrology changed and soil formation commenced.

As mentioned above, seven cores were taken in this area (Figure 6.21). These cores have not been described in the laboratory as yet, and so descriptions are taken from Dr Rob Homsher's field notes. Cores 2-4 were taken just west of the deep trench but because the area was too disturbed and the corer did not work properly, these will not be described in any detail. One core, C3, contained a possible fining up sequence, starting with pebbles at about 3 meters down, shifting into silts and then silty clay before soil formation at 1.5 meters down; these are probable channel deposits. As it is not as deep down, it postdates the earliest channel in the deep trench and predates the latest channel. As with the deep trench, soil formation seems to start at 1.5 meters down. Core C1 consisted mainly of slope wash and colluvium, with a gravel base at 1.9 meters. It was taken from the far side of Gurga Chiya, and reflects its position on the slopes of a Pleistocene terrace.

Cores C5 to 7 are perhaps the most informative, despite not having been described in detail. C5 is closest to the deep trench and its stratigraphy closely resembles the trench, cores C6 and C7 are progressively closer to Gurga Chiya and are at slightly more elevated positions (Figure 6.21). The Pleistocene gravels are somewhat deeper here, starting at about 7 meters down. This seems to be a deeper section of the original channel carved out in the very early Holocene or during an interglacial period (see below). In any case, there is a sharp boundary which is overlain by a light yellowish brown (10YR 6/4) with some mottling (brown sediment, 7.5YR 4/4). Unfortunately the grain size is not recorded. This layer may possibly be correlated temporally with OST1-1; this layer also contained some areas of mottling (OST1-1a). However, the colours do differ considerably and it may be that this represents more 'traditional' channel deposits, i.e., a sandier layer, but without knowing the grain size, this is impossible to know.

In either case, this is overlain by clay (no colour given), and this perhaps is the end of the fining up sequence for the original channel deposit, or is associated with OST1-2. OST1-2 may have been completely eroded away by the channel deposit (gravels) that were encountered around 3.5 to 4 meters down. This likely correlates with the channel cut encountered especially on the east side of the deep trench, cutting into OST1-2, which is also about the same depth. C5 and the trench lie on the same trajectory going towards the confluence. The overlying sediments (below the soil horizons, are described as clay with no other real information given. This will probably be correlated with OST1-3 and OST1-5, once this core is more carefully examined. The final gravel cut found in the trench is not detected here, this may be due to the position of the channel.

Core C6 is similar, with Pleistocene gravels starting at about 5 meters down, with a pinkish matrix similar to what was found in the deep trench; this is overlain by clays. There is a channel cut again evident at about 4 meters down. While it is possible that this gravel layer is the same channel as detected in C5 and the deep trench, it is also quite likely that it is another branch of the stream system, which is also flowing into the confluence area (modern dam lake). C3, as mentioned above, also has a channel cut at about 4 meters down and is likely the same branch as seen in C6. In C6, deposits of brown silty clay overlie the channel, however there is no detail yet of depositional episodes. These will likely correlate with the upper layers of the deep trench.

The final wadi cut, as in C5, was also not detected in this core. It should also be noted that there are two wadis that run in the same direction as the proposed streams seen in C5/deep trench and C6/C3. One runs east of C5, near Bakr Awa, and the other runs east of C6 (see Figure 6.21). Although the climate system has changed, this indicates that the hydrology is somewhat similar today, with several active (although seasonal) channels running parallel to each other. The channels in the past were bigger, with increased sediment load and water discharge, and likely perennial with seasonal flooding.

C7's Pleistocene base starts at about 3.5 meters down, showing its position further up the original terrace. This is overlain by sandy clays and clays. This deposition would have occurred much later in the Holocene, perhaps around the time of the deposition of OST1-3 or 4, and could reflect channel movement. Before this deposition, this part of the Pleistocene terrace would have been exposed.

There seems to be a huge channel cut into the Pleistocene terrace. The deepest part is closer to Bakr Awa, and it becomes shallower towards Gurga Chiya, as indicated by the varying depths to gravel in the cores (Figure 6.21) and trench. This is also reflected in the modern topography. It seems that prior to the Holocene sedimentation, the stream power was much higher, and a gravel bed braided river characterised the alluvial environment. At this point, the dating of the formation of this original channel is unknown: it could be from an interglacial period or the very early Holocene.

Gravel braided rivers are common in areas like this, and are highly dependent on seasonal flow, with high discharge at certain times (such as snow melt). This is a montaine environment, with a narrow valley. There are steep slopes and high sedimentation, which result in high stream flow and thus the formation of multiple-branched braided rivers. The Pleistocene gravels certainly are indicative of these river systems. Where cuts in these terraces were observed, the sediments were made up of compact, imbricated (showing direction of flow) gravels (Figure 7.9), divided by sharp boundaries where erosion occurred before the new layer of gravels was laid down.

Rivers such as the Tanjero and Mawat (Figure 7.10), investigated by our team for a separate climate project, are very typical of mountain river systems, and alternate between braided rivers and single channel meandering rivers, depending on slope and discharge. These are major channels and transport large volumes of water from the mountains into the valleys below. They are mainly gravel bed braided rivers, although there were some sands and muds in the slack water areas.

The sedimentary record in the area between Bakr Awa and Gurga Chiya, however, seems to differ from these modern rivers and from what occurred

Figure 7.9: The imbrication of the gravels indicate direction of water flow

Figure 7.10: The river Mawat

in the area during the Pleistocene. The sediments are primarily composed of reddish clay rich silts, which vary only in clay and $CaC0_3$ content, with channel cuts, usually associated with lag (gravel) deposits. No sedimentary boundaries were clearly evident, although there were some hints at graded boundaries, shifting from one grain size into another, and/or slight differences in colour and nodule composition. There were no sedimentary structures either. Sand may be present in the massive clayey silt deposits and in gravel cut towards the top of the section of the deep trench, but there were no sand layers.

This sedimentary record seems to rule out a braided river system with associated braidplain (see Reading 1996, Boggs 2001), however, there is evidence for multiple channels and abrupt chute cut offs or flood channels. It is possible that this area is characterised by an anabranching system, i.e., one composed of multiple active channels which avulse (as oppose to meander) across a section of the plain (see Brown 1997, Richards *et al.* 1993).

The banks of the channels were composed of mainly muds, which would have made them cohesive. As such, it would have been more difficult for the channel(s) to migrate (meander) across the plain and so avulsion would have occurred (see Brown 1997). Avulsion, or channel jumping, occurs mainly in flood periods, whereby a channel jumps to another one (often a palaeochannel), which is lower in elevation in the plain. In addition, because the sediments are predominantly muds, and do not exhibit the usual fining up sequences found in channel deposits, it is possible that these channels are cut-off chutes, i.e., channels created during flooding events which were then cut off shortly after creation, and filled up subsequently with silts and clays (Brown 1997).

Areas of multiple channels are often swampy and marshy, and the areas of mottling, especially in the east section, attest to the wetting and drying (redox) that this area would have gone through. In addition, the digital elevation model (Figure 7.11) indicates that this is an area with many areas for water to flow, with one of the most concentrated areas being just west of the deep sounding. This part of the terrace is very deep, however, it is not the deepest area of sedimentation. As can be seen in Figure 6.21, the deepest part is situated southwest of the deep trench, where Core 5 reached depths of about 7.5 meters. It may be that in the earliest part of the Holocene, the/a river channel(s) was located here.

The high level of channel cutting and erosion has implications for any palaeoecological reconstruction in this area, the main effect is making it very difficult to do anything that is very detailed or robust. The poor preservation of phytolith assemblage also adds to the difficulty.

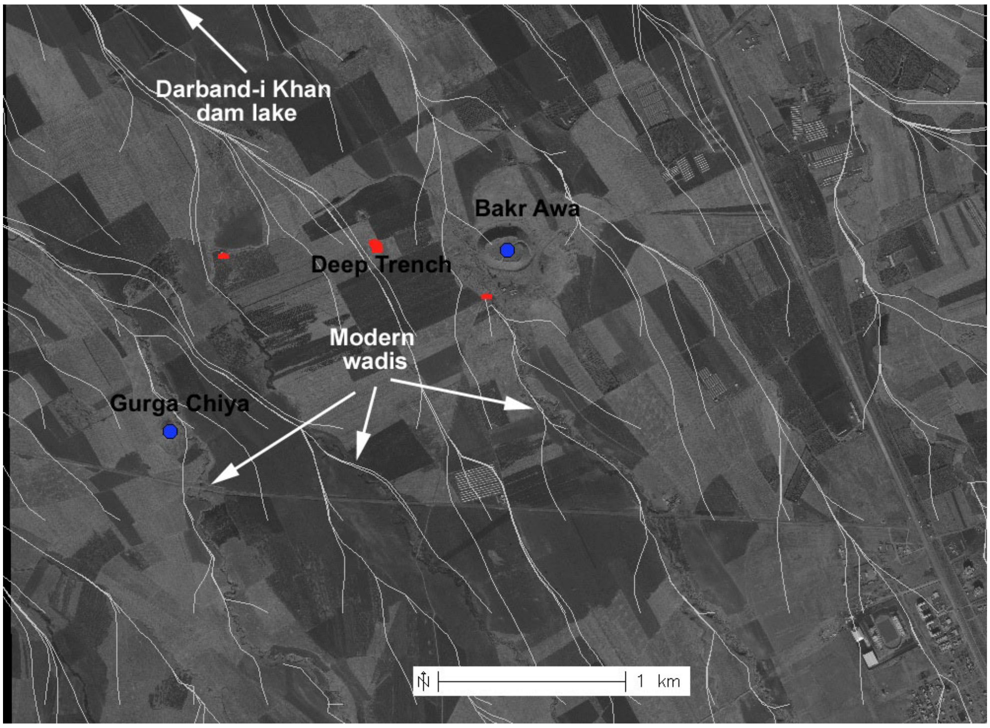

Figure 7.11: Digital elevation model placed on top of a satellite image of the Bakr Awa region showing potential areas for water flow. Modified from image courtesy of Mark Altaweel

The area around the deep trench and cores C5 and C6 would have been swampy for the majority of the time, until the Achemaenid period. It is very unlikely that any farming took place in the immediate vicinity (although it must have taken place elsewhere on the plain), however, there would still have been resources that could have been used and managed and this will be discussed below.

Yasin Tepe and environs

The area around Yasin Tepe was investigated in 2011 and 2013; three trenches were excavated (G30, 32, and 33), one wadi section (G14) recorded and a core was also taken. Phytolith samples were taken from the three trenches (to be analysed later) as well as from the wadi section, interpretation of which will be included here.

Three samples were also taken from the banks of the Tanjero river for OSL dating (awaiting results) in order to better understand the evolution of the river channel. Yasin Tepe is slightly different in that it sits on an outcrop rather than a Pleistocene terrace. As such, the movement of the channels will be somewhat constrained by the underlying hard rock lithology.

In 2011, a riverbed section was photographed, drawn and sampled. On top of Pleistocene (blue and pink layered) gravels were small layers of alternating silts and sands, with charcoal throughout. This is a Holocene period terrace, however it has not yet been dated (charcoal samples were taken for dating). This is an area that may have been farmed, the charcoal indicating perhaps field burning.

The layers alternate between clays/silts and fine grained sands, but towards the top, there are minor layers of coarser sand, possibly indicating minor flash flooding episodes. The sediments are much greyer here, falling in the 10YR range, and resemble much more typical alluvial channel sediments.

Three phytolith samples were analysed, mainly to see if there is a difference in preservation in this area compared to the Bakr Awa area. At this point, without dates, there is no way to correlate this with the Bakr Awa sediments. Two of the samples came from sandy contexts, one from silt (see Appendix J).

The phytolith abundance was generally better than that of Bakr Awa, however, the numbers were still not very high, ranging from about 1000 to 8000 phytoliths per gram of sediment. There were very few multicells. The sandy deposits contained more diatoms and spicules, perhaps a reflection of the overbank deposition; and it should be noted that there were very few of these present in any case. Monocotyledons dominated the assemblage with more than 87 per cent. Jigsaw morphotypes were represented, which could indicate wetter forest conditions, however the overall dicotyledon count was low, perhaps indicating that the forested area was further away.

Despite the higher abundance of phytoliths, however, there was still much dissolution and there is no evidence for land surfaces. One tentative possibility is P042, the silt layer, which seems to indicate a more wetlands environment, with some (wild) grasses nearby. Only one unidentified cereal multicell was found in the three slides, again begging the question, where did farming take place?

In 2013, as discussed in Chapter 6, three trenches (G30, 32 and 33) were excavated, recorded (see Figure 6.23) and sampled. In the three trenches, the sedimentation is similar: clays overlain by silts. The sedimentation is slightly different to the Bakr Awa in this area, but somewhat similar to that in Bagum (see below). Unlike Bakr Awa, there are no channel cuts, instead these are more typical floodplain deposits, which change in grain size (from clays to silts) slightly as the channels migrate across the plain. Although there is still a lot of clay in the sediment, there seems to be a higher silt (and perhaps sand) fraction, thus making the banks of the channels somewhat less cohesive. It may be that there was less avulsion here of the channels, and more meandering. The current sinuosity of the river and related channels do suggest meandering now. In Trench G32, there was an anthropogenic cut (channel) into the top soil. Thus it is rather modern. It may have been dug in order to divert water to or from the terrace area, most likely the former.

Bagum to Shamlu transect

Three trenches were excavated, sampled and drawn in this transect; the samples await analysis. However, some preliminary observations can be made based on the drawings. The main problem with this area is the close proximity to the Darband-i Khan dam lake, which was created in the 1960s with the building of the dam. Not only did this lake have a devastating effect on the archaeology now submerged, and the ecology of the river system (confluence of three major rivers), the sedimentation and buried sediments were also adversely affected. When the dam was originally constructed on the Diyala, the area behind the dam was submerged. This submerged area fluctuates during the seasons (some of the submerged sites become visible above the water during the summer), and this seasonal fluctuation will have an impact on the sediments in terms of geochemistry and most likely stratigraphy.

As described in Chapter 6, the sediments here were similar in consistency, in that they were mainly clayey silts, however they were mostly grey or grey brown in colour. The difference in colour could of course be caused by the parent material being different, however, this seems unlikely given that there rest of the plain, as far as investigated, seems to be made up of very similar, clayey silt reddish sediments with intercalations of sands and gravels. A more likely possibility is that these sediments were originally reddish sediments derived from the terra rossas, however, due to the dramatic rise in the water table, the sediments were changed to the grey colour (reducing conditions change the ferrous oxides into ferric oxides, causing the oxidised red colour to go grey or black (see also Wildman *et al.* 2010).

This fluctuating watertable will likely have had an impact on the sediments in terms of translocating clays from layer to layer, and this might also impact the smaller microfossils such as phytoliths and diatoms. The fluctuation will also be seasonal, the dam lake levels are lower in the summer and some submerged sites become visible. In fact, in trenches G35 and G31, there were some reddish sediments, mottling, seen in the sections. This may be due to the redox effects of the fluctuating water table (for instance, redox effects could be seen via geochemistry after only a short period of time of submergence and oxidisation at Lake Powell, Utah and Arizona: Wildman *et al.* 2010). Samples were taken from the trenches, but any results are likely to be problematic as a result.

However, although a fuller analysis, particularly that associated with vegetation change, may not be possible with these sections, there is still information that can be gleaned. As with the other two main areas described above, there is again deep sedimentation and at least one channel cutting through the Pleistocene terraces. Near the site of Bagum (Halaf period), which sits on a Pleistocene terrace, trench G35 had a depth of around 6 meters, but the Pleistocene gravels were not reached. This area of sedimentation may be deeper that that of the large trench near Bakr Awa. The exact depth was not obtained due to the fact that the watertable was high and water was rushing into the trench.

At Shamlu, where trench G31 was located, the depth was about 3m, but the Pleistocene gravels had not been reached, again because of water table issues. And west of Bagum, the depth of G34 was about 3.5 meters, before the Pleistocene gravels were located. Preliminarily, it seems as if there were at least two major channels, one on either side of Bagum, which dug through the earlier Pleistocene terrace(s), remnants of which provided the locations of Shamlu and Bagum.

The Total Station results (see Figure 6.24) indicate that the topography increases in elevation moving away from Bagum towards G34. This could indicate that there is an underlying Pleistocene terrace, covered by Holocene sedimentation. The elevation dips down towards Shamlu, which may be due to topography, as it is going down towards the old confluence of the three rivers. These initial channels can not be dated, however, it is possible that they were created at around the same time as that of Bakr Awa, at the beginning of the Holocene. Alluviation patterns, unfortunately, have been compromised by the dam lake effects.

Comments

The offsite sedimentary evidence from across the plain graphically illustrates a changing environment, mainly due to hydrological shifts and movements. The gravel cuts seen in many of the sections indicates not only this movement but also the high volume discharge that occurs during the formation of these new cuts. This is a montaine landscape, although deceptively flat, is very near much higher elevations which increase the stream power of the rivers. This in turn impacts the sedimentation patterns found in the valley/plain itself. In the Bakr Awa region, the sedimentation patterns are driven by the anabranching nature of the channels. There appear to be channels that were cut during periods of flooding, only to be abandoned shortly thereafter, producing waterlogged, lake type areas. In other areas, the sedimentation is more similar to typical overbank deposits, such as that found at Yasin Tepe and Bagum.

The phytolith evidence, although fragmentary, may indicate a riparian environment, that of wetland trees and shrubs as well as sedges and reeds, with a hint of grasslands and agriculture in the vicinity. The question still remains as to where on the alluvial plain farming actually took place.

7.3.2 Discerning land and resource use from onsite phytolith data

Introduction

The onsite samples are all from the site of Bakr Awa, and will as such be compared to the offsite samples from the deep trench. Onsite samples from other sites have and will be collected and analysed in the future again for comparative analysis to better understand vegetation and land use change over the Holocene throughout the plain.

The preservation of the phytolith record was much better onsite at Bakr Awa as expected; reasons for this were discussed in Chapter 5. There was variability in the samples, however, with lower preservation in some of the floor samples (perhaps as they were swept away) and very high number in Sample 115/2306, in what was described by the excavators as a 'white layer'. I did not collect this sample personally, but I suspect that this was a layer of pure silica, a result of a fire or decomposing vegetation deposit. There were certainly more multicell phytoliths in the samples, and some were very large, consisting of 100+ conjoined cells. This included both wetland plants and cereals. Diatoms were also present in some of the samples.

Some of the phytoliths also appeared to be melted or warped (see Figure 6.34). It seemed as if these had been subjected to high temperatures, such as a kiln, but they only come from floor samples and are not always in association with burnt phytoliths. Indeed, two of the samples that contained warped / melted phytoliths come from the Old Babylonian (OB) house (see below and Figure 7.13), in a room (103) located next to room 105, which contained a large oven with remains of vitrified pottery inside (Miglus *et al.* 2013). The melted phytoliths were subjected to a very high temperature (at over 900° centigrade, phytoliths start to become 'distorted': Elbaum *et al.* (2003; p. 224)), as was the pottery which must have been subjected to temperatures over 1000° centigrade; it is likely that these are somehow related.

The samples were collected by myself and Ms Kristina Sauer, from the excavations in the lower town (the citadel excavations have not yet reached Bronze

Age levels). The samples mainly come from floor contexts, and range in date from the late early Dynastic, through the Akkadian (see Figure 7.12), Old Babylonian (see Figure 7.12 and Figure 7.13) and LBA periods. The dating is based mainly on typology, although some C14 dates were also obtained (Miglus *et al.* 2013). The ED date is based on an AMS date of 2620-2570BC but ceramic evidence could push the dating to EDI (Miglus *et al.* 2013). This section will discuss the various strategies that are hinted at in the phytolith evidence, arranged according to the three niches (arable, woodlands and wetlands), in a time progressive manner (from the late ED into the LBA).

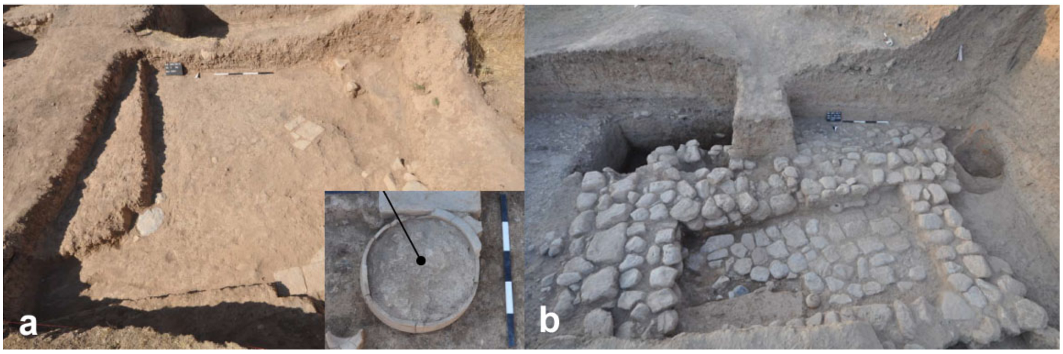

Figure 7.12: a: Room 103 of the Old Babylonian house. One sample came from the floor (106/2261) and another from the pot (detail; 108/2264). b: The Akkadian / post-Akkadian shrine, where four samples were taken. Photos courtesy of U. Bürger and K. Sauer, modified

The arable niche: crop plants and agricultural strategies

Unfortunately, because there has been no macrobotanical analysis at this site, the crop plants discussed will be limited to those in the phytolith assemblage. With that in mind, however, some trends can be discerned in terms of crop choice and agricultural strategies.

The main aspect is, of course, cereals, and although ubiquitous throughout the time period covered by the samples (ED to LBA/IA), there is variation in the absolute counts. As mentioned above, most of the contexts are floors, which are not always the best contexts, as they are often swept up. However, the fact that the contexts are similar may give us some information regarding activity areas, particularly when there is a range of samples in a particular time period. Unfortunately, many of the cereal multicells were not identifiable to genus level, and this will affect somewhat the results and interpretation, particularly corre-

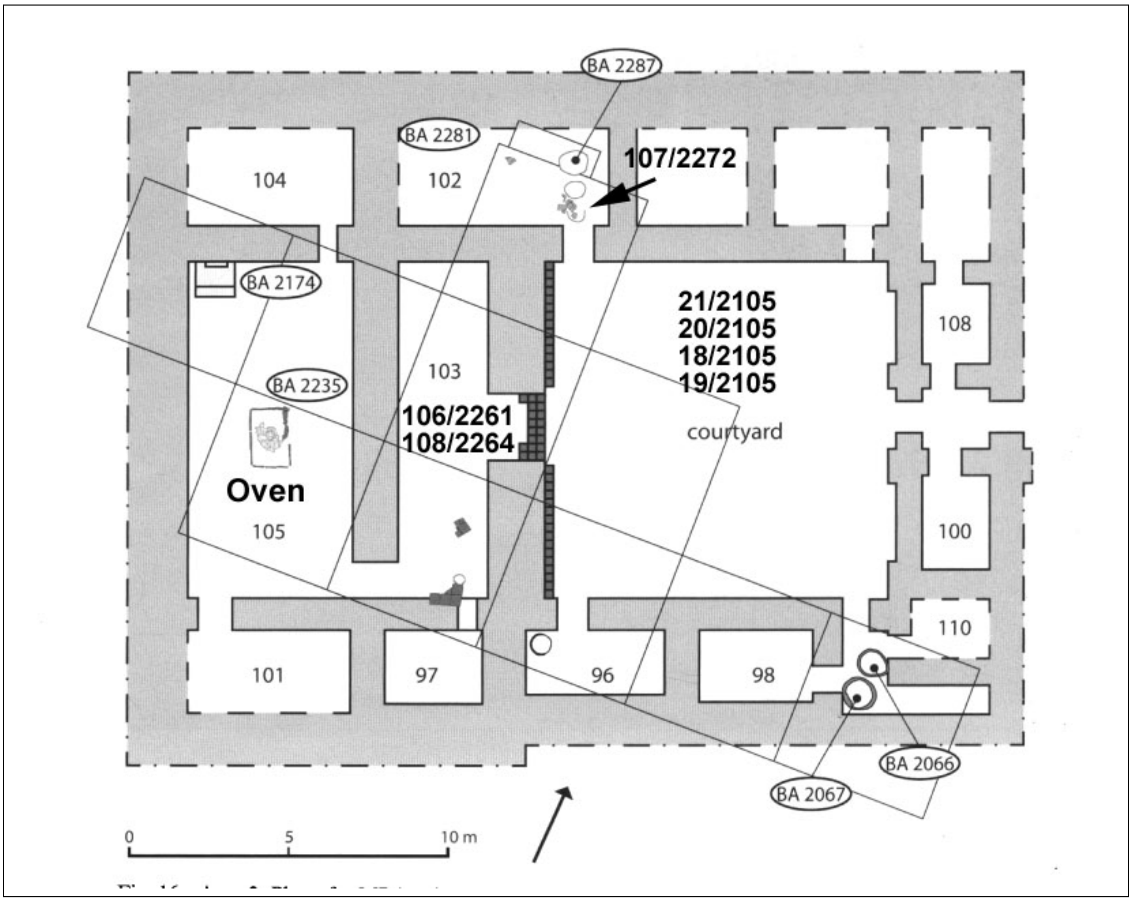

Figure 7.13: Plan of the Old Babylonian house, with locations of OB period samples. Modified from Miglus *et al.* (2013), p. 54, Fig. 16

lations.

Tentatively, it seems that barley and wheat were both present from the Early Dynastic through the Akkadian period, then in the late third millennium (UR III), there is only barley (see Figure 6.35). During the Old Babylonian (the best represented period in the samples), both barley and wheat are present, and then going into the LBA, only wheat is represented. This, of course, could be biased because of sample size and identification issues. The Ur III period, for instance, is only represented by two samples. Wheat and barley are not present in every OB sample, so it may be that there was wheat in the Ur III period, but just not in the samples here.

The two ED samples (although one possibly dates to the Akkadian period), contain the most number of cereal phytoliths. There is a strong positive correlation between the wheat, barley and weeds, suggesting that they have come in together, at least in these two contexts. So the wild grasses are agricultural weeds, rather than fodder. There is a strong positive correlation between husks and stems, indicating that processing or storage took place in these contexts (which would also account for the high number of phytoliths).

Moving into the Akkadian/post-Akkadian period (2270-2040BC; the 22nd century is the most likely range: Miglus *et al.* 2013), the samples come from a shrine room (or *Herdhaus*: Miglus *et al.* 2013) with five fireplaces. There is a weak correlation between wheat and barley and between wheat and agricultural weeds (see Table 6.6). There is a slightly stronger correlation between barley and weeds. This suggests that barley and weeds are coming in together as fodder (see Ryan 2009), and the wheat is fairly clean of weeds. There is also a fairly high correlation between cereal inflorescences and stems, again suggesting processing or storage of cereal; a grinding stone was also found in this room (Miglus *et al.* 2013), which adds credence this idea. In the fireplace samples, there are weed and barley phytoliths, and dicotyledon leaf phytoliths (as well as dicotyledon wood phytoliths, see below), possibly indicating the use of dung fuel. This could further strengthen the idea that the barley was being used as fodder for animals and not for human consumption. However, this is still based on a few samples, which come from one room. The white layer will be discussed more fully below. Not much else can be said in terms of cereals in this period, except that there may (and this is only a possibility) be a shift in diet from consumption of both barley and wheat to only wheat.

The UR III period, wrapping up the end of the third millennium, contained no wheat phytoliths and so correlations could not accurately be calculated. There is a strong correlation between weeds and barley, and a strong negative correlation between cereal inflorescences and straw. There may have been storage of barley or fodder in one area, as indicated by the high amount of barley and weed phytoliths in sample 101/2232. It is not possible, especially if this is just indicating the storage of fodder, if there was a decline of wheat consumption in this period.

The Old Babylonian period is best represented in the samples analysed here, mainly because this was the most extensively excavated period (thus far). However, most of the samples come from one house (see Figure 7.13), so it should be borne in mind that trends are tentative.

Generally speaking, the correlations between wheat, barley and weeds seem to indicate that wheat is consumed, and barley is coming in with the weeds, possibly indicating that it is the weedy or wild type and being used as fodder. Unfortunately, there are no hearth samples here so looking at the evidence from dung is not feasible. There are several different contexts, however, that might shed some light on this. Four of the samples are floor samples taken from the same area, the courtyard (18/2205, 19/2205, 20/2205 and 21/2205; see Figure 7.14). There were very few cereal husks here, and indeed very few phytoliths overall. In any case, the only identifiable cereal husks were that of wheat, and there does appear to be some sort of covariance between the husks and straw. So perhaps there was some storage of wheat, or processing in this area. The latter is more likely as this was an outdoor area.

Figure 7.14: The courtyard of the Old Babylonian house

The correlation between weeds and barley may have been skewed somewhat by context 2264, the oldest OB level (room 103). Two samples were taken from here, which are a little odd. On the floor, there were unidentified husks with straw and weeds, which could indicate processing/storage, however, in a pot found in the context, there was also a substantial amount of barley and straw, with weeds outnumbering them. It is difficult to interpret this, it may be that the pot is not reflecting contents kept in it *per se*, but rather fill from this context. Perhaps fodder was stored here. This was also the room next to the oven, and which contained a number of warped / melted phytoliths (see above).

In the LBA contexts, no barley was identified. There was, however, a moderate correlation between weeds and wheat and a strong correlation between cereals and weeds. Straw was also found in most of the floor contexts. These come from different floors and may be indicating domestic activity revolving around the processing/storage of cereals.

It is unfortunate that the preservation of the multicells was not particularly good, and thus did not allow for more firm identification of cereals to genus level. It seems that overall, wheat was preferred, and that barley was sometimes for human consumption and sometimes only for fodder. Indications from sedimentary evidence shows that there was certainly ample water for the propagation of wheat throughout the Holocene (as indeed there is today).

Some possible fruit/seed phytoliths were also identified in a few samples, but not in any significant numbers. There is, however, some corresponding evidence from the offsite samples of horticulture.

The wetlands niche

The wetlands niche in this case incorporates more the sedge and reed type plants as opposed to trees and shrubs. But it is important to note that there is a blurring between woodlands and wetlands. In any case, wetland plants are ubiquitous through the site, both spatially and temporally. Both sedges and reeds are found in all time periods, with sedges being more common. Reeds and sedges would have been used for a number of purposes including thatching, bedding, flooring / bedding, mats (see Figure 7.15), baskets and so on.

In sample 101/2232 (third millennium floor), there is a spike in wetland plants, especially for *Phragmites* sp. It may be that this is reflecting roofing or bedding / matting material in this room. In a later OB context, in room 102, there was another white layer, which has been interpreted as a reed mat (Miglus *et al.* 2013; this has been sampled but not yet sent to me for analysis). In all of the indoor floor levels, sedges and reeds are found, possibly indicating the use of mats in these spaces. The only floors where there are very few wetland plants are the samples from the outdoor courtyard area, where presumably mats were not used.

The use of wetland plants is not surprising given the alluvial context of the site. The temporal visibility of these resources shows that wetland plants were readily available throughout this time period, which indicates that there were marshes in the alluvial plain. This is also suggested by the offsite microfossil and sedimentary evidence. There may be less use of these resources in the LBA.

Figure 7.15: Reed matting in the dig hut

The woodlands niche

Dicotyledon single cells were found in all contexts, and represented leaf and wood / bark parts. There aren't really any temporal trends, the differences in numbers seem to be based more on context type. The floors, generally, had fewer dicotyledons represented, although the LBA floors had more than the OB levels, especially in the numbers of bark / wood morphotypes. Perhaps there was more use of timber in the structures at this point? There is a spike in context 115/2306, the layer of silica on the stone pavement of the Akkadian shrine. The monocotyledons (wetland plants and cereals) still dominate, but dicotyledonous plants (trees and/or shrubs) make up a substantial portion of the assemblage. One option could be that cereals and herbs were stored here in baskets made of sedge or phragmite leaves.

One of the five fireplaces located in the shrine also contained wood as well as leafs (and cereals and weeds), indicating the use of both dung and charcoal as fuel types.

The dicotyledon evidence is meagre, but overall there seems to be a continuous supply of woody plants used by the inhabitants. If the offsite interpretation is correct, the people would not have had to travel far for a supply of wood. However, if they were using timber for structures (as well as mudbrick), they may have been sourcing this from the uplands as well. More work needs to be done on any macrobotanical remains of timber to understand what they are using and where they are sourcing this material.

Water management

Water availability and possible effects on conjoined cell size was discussed in Chapter 5. In the samples from Bakr Awa, there were many that contained multicells that consisted of 10 or more cells. In several samples, there were 100+ cell multicell examples (see Table 6.5). These large multicells were found across the temporal range and indicate that high water availability was present from the ED through the LBA periods. An interesting point is that some of the large multicells were those of wild grasses, which indicates that other grasses also 'react' to increased amounts of water.

The next question of course is whether the water availability was due to natural flooding/precipitation or to irrigation. The sedimentary and offsite evidence suggests that it is the former, that water was certainly not in short supply. There does not seem to be a hydrological shift until the Achemaenid period (*circa* Iron Age). It would be interesting to see if there is a fall in large multicell in the later period samples.

7.3.3 Concluding comments

This chapter has discussed both the phytolith and sedimentary evidence from Hirbemerdon Tepe and Bakr Awa / Shahrizor region and how they can be used as proxies to understand how the environment changed over time, both on a local and regional scale. They are both powerful datasets by themselves, however, when combined, can add details that might otherwise be missed.

Onsite and offsite datasets can also be used very successfully together in order to better understand how people used and managed resources and land in their environments, and how these may have changed over time. Although much research has been carried out on onsite samples to understand resource use and crop choice onsite, little has been done in combining both onsite and offsite datasets, to better understand agricultural practices and land / resource use.

The next chapter will focus on this latter aspect, but through the framework of niche construction.

Chapter 8

Interpretation II: The cultural niche construction perspective

8.1 Introduction

There is often a dichotomy between what is perceived as a ’natural environment’ and a landscape that has been modified by humans. As such, discussions can often be limited to hunting and gathering versus agriculture and domestication. There has, of course, been research into the agricultural spectrum, and a recognition that people don’t always just ’do’ agriculture, or just hunt and gather (Harris and Hillman 1989, Ertuğ-Yaraş 1996). Certain theoretical approaches, such as domesticated landscapes (see Terrell *et al.* 2003, Chase 1989, Erickson 2008), do go some way in understanding and seeing that prior to genetic domestication of plants and animals, environments were already being domesticated: that is, certain species of plants and animals were actively being encouraged or discouraged in certain areas.

However, the theoretical approach of domesticated landscapes (see Erickson 2006, Terrell *et al.* 2003) is applied to pre-agricultural societies, and although there is recognition that ’later generations benefit from the labor and knowledge of their ancestors embedded in landscapes’ (Erickson 2008; p. 161), it seems too descriptive, more focused on the end result (the modified landscape as it is now) rather than on the mechanics or processes of change.

Niche construction theory, as discussed in Chapter 4, is a framework that looks at how organisms live in and change their environments, in other words, the mechanics of change as well as how the result affects that environment. Niche construction posits that not only do organisms adapt to a 'pre-existing environment', but they also alter this environment (Laland and Brown 2006; p. 95). These adaptations could, for instance, be an effort to 'damp out variability in environmental conditions' (Laland and Brown 2006; p. 95) – modifying the environment to make it more reliable and predictable. Channel irrigation, for example, could be implemented to ensure a regular water supply to fields despite unpredictable precipitation patterns.

The modifications of the environment, or more accurately, microenvironments or niches, and the knowledge needed to make these modifications, constitute the ecological and cultural inheritances that are passed down from one generation to the next. Thus, niche construction theory can be used to explain and understand environmental change, land use patterns, resource management, socioecological change and many other issues that arise in archaeological research.

The final research question: 'How can sedimentary and phytolith evidence be used, in conjunction with other datasets, to elucidate on human modification of the environment and ecological and cultural inheritance as posited by cultural niche construction theory?' will be addressed here. This chapter will discuss the evidence in the framework of niche construction, using the models developed in Chapter 4, to show how phytolith and sedimentary evidence can help to explain how humans have modified the environment, over a period of time and what the resultant ecological and cultural inheritances are. This chapter will show that, despite the fragmentary evidence there is great potential in these two proxies to help in the understanding of past human decision making and long-term implications on the environment and societies.

This chapter will be structured a little differently than the preceding one, divided not by site but rather by niche (arable, wetlands and woodlands). Models will be presented for the two sites and for different time periods, to show how niche constructing activities may have affected these niches over time.

8.2 The arable niche

8.2.1 Introduction

The arable niche, as discussed in Chapter 4, encompasses different aspects of farming and animal husbandry (see Figure 4.4). These activities can include vegetation clearance, field burning, irrigation and other strategies, which will all modify the environment. The modified landscape is inherited by the next generation (the ecological inheritance), who will also inherit knowledge of farming and husbandry strategies (the cultural inheritance). They may choose to respond to the changing / changed environment or not, and both of these choices will also modify the landscape, which will then be handed down to the next generation and so on and so forth.

This section will discuss, as far as possible, the ecological and cultural inheritances through time both at Hirbemerdon Tepe and Bakr Awa.

8.2.2 Hirbemerdon Tepe

Introduction

As discussed in Chapter 7, there is evidence of continuing habitation at Hirbemerdon Tepe from the EBI (3000BC) through to the MBA (1782BC). There is also corresponding phytolith and sedimentary data for most of this period. Although there is some evidence from earlier and subsequent periods, there is no continuity (e.g., from the Chalcolithic to the EBI and MBA into the LBA and beyond), so it is more difficult to gauge possible CNC activity.

Early Bronze Age (I-IV)

There is a break in habitation from the Chalcolithic going into the EBA (from *circa* 3500 to 3000BC). The offsite phytolith record possibly dates to about the onset of the EBI or thereabouts (see discussion in Chapter 7). The sedimentary layers (and corresponding phytolith samples) for the EBA include T01-7 to T01-5 in the terrace trench and G02-4 to G02-2 in the terrace sections (see Figure 7.2).

Cycle 1: EBI-II (Figure 8.1)

The first cycle of CNC modification covers the EBI and II, although as seen below, there is continuity into the EBIII and IV. The EB period is divided, mainly for ease of comparison.

Traces of the EBI and II phases were found onsite (see Table 3.1 for details); unfortunately no phytolith samples were obtained for this period. However, there are some offsite samples that could give information regarding landscape modification and CNC activities. The scenario described is very tentative, due to the fragmentary phytolith evidence and lack of firm dating, but it does hint at the possibilities of using phytolith and sedimentary evidence in a niche construction framework.

According to the phytolith evidence for this period, there appears to be some indication of riparian vegetation clearance, giving way to arable land (see Chapters 6 and 7). The sedimentary evidence seems to indicate that there was active alluviation in layer T01-7, with perhaps some occasional flash flooding, although this is not necessarily evident. If there was indeed regular alluviation, this would enable flood farming to take place, once land was converted to farming. Phytolith sample T01-7 indicates a more riparian type vegetation, with dicotyledons (only short cells) and wetland plants making up the majority of the phytoliths (see Figure 6.8 and Appendix G).

It is likely that when the settlement at Hirbemerdon Tepe was founded, the alluvial environment consisted of riparian forest around the Tigris channel, and perhaps opening up into open woodlands or possibly grasslands in the more distal areas of the floodplain. This was already a modified landscape, inherited from the earlier Chalcolithic and Neolithic settlements, where some of the terrace (perhaps different areas) was cleared for farming and grazing. With the 500 years or so of possible lack of habitation, there would have been reversion back to a riparian-type environment.

In any case, at the start of the EB, it is likely that the inhabitants needed to clear areas in the terrace for farming and grazing. The land was cleared (possibly using slash and burn as indicated by the charcoal content), and there is a resultant rise of grasses in T01-7a. The percentage of dicotyledons do remain

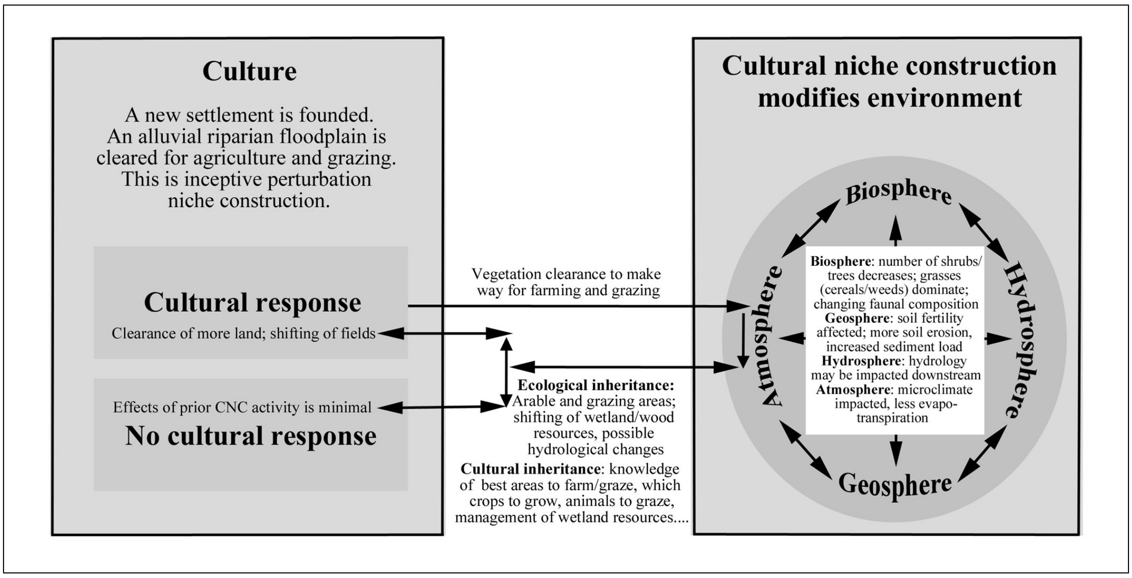

Figure 8.1: The arable niche during the EBI and II: the original vegetation is starting to be cleared away in both parts of the terrace. This leads to changes in the microenvironment, in terms of the different spheres, which in turn leads to the modification of the microenvironment. This is the ecological inheritance that is passed down. The cultural inheritance encompasses any knowledge of best practice farming and husbandry in this region. The next generation is faced with two choices, to employ different CNC strategies or to continue to use the ones already in place.

fairly constant from T01-7 to 7a, however, and it may be that this area was not completely cleared of riparian vegetation.

Another possibility is that this area may have been (partially) cleared for grazing of cattle or sheep. There is no faunal evidence from the EB period at Hirbemerdon Tepe, so this is pure conjecture. G02-4 is generally temporally related to T01-7, but it is impossible to say if the sample predates or postdates T01-7/7a; it also seems to reflect a somewhat drier period. However, again there are indications of modification of the environment: there are fewer dicotyledons and wetland plants here. If the area is indeed temporally related to T01-7, then it may be that it was slightly more cleared of vegetation.

Thus there is CNC activity: (partial) land clearance to make way for either arable or husbandry practices. This would have had ramifications for the soils, sediments, vegetation, animals, hydrology and atmosphere in the microenvironment, including loss of soil fertility, increased erosion, a shift to grasses dominating, to name a few. There may also have been impacts to the alluvial environment further downstream in terms of sedimentation and hydrology.

A new landscape would have been inherited by the next generation at Hirbemerdon Tepe, and the farming knowledge passed down as well. The question is how did the inhabitants respond to this changing environment? Was there a response in terms of changing strategies, for instance clearance of more land to take the pressure off of existing fields? Or did they continue as before, because perhaps change was not necessary or perceived as necessary? When looking at the next period (EBIII to EBIV), we can see both continuity and change.

Cycle 2: EBIII-IV (Figure 8.2)

Moving later into the EB, there are hints hints of changing strategies. G02-3, which seems to reflect a period of higher water availability again, also continues the trend of increasing grasses over wetland plants. There is, however, one added aspect to the arable landscape, that is, possible horticulture. Horticulture, as mentioned previously, requires more commitment to the land: trees take years to mature and bear fruit, unlike cereal crops which mature in a matter of months (Zohary *et al.* 2012). In addition, they are more permanent features in the landscape. Unlike other crops, it is difficult to shift fruit tree plots around, and so decisions to use a different area for horticulture will take much more forward planning.

Aegilops sp. was the only grass identified unfortunately, however, this could be an agricultural weed and so it is possible that the remainder of the grasses are either agricultural weeds and cultivated cereals. It is more likely that this area was used primarily for horticulture, and the grasses were blown in from elsewhere on the terrace or there were wild grasses growing between the trees.

T01-6 is probably contemporaneous to G02-3, and likely dates to the EB III/IV period of the site. As noted in Chapters 6 and 7, there were very few phytoliths, however, there were some very large (100+ conjoined cells) multicells, that had little dissolution or fracturing. It seems that where before this part of the terrace may or may not have been used for arable purposes, by this time, they were using it to grow emmer wheat. In addition, they were floodwater farming, judging by the size of the multicells. The presence of jigsaws in onsite contexts and the low water stress levels offsite also corroborate this.

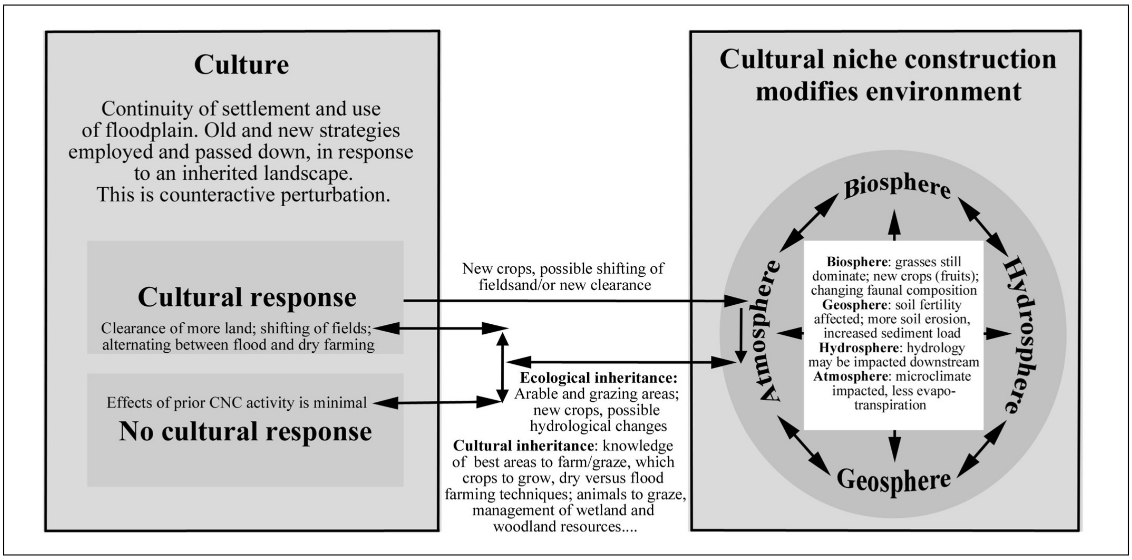

Figure 8.2: The arable niche during the EBIII and IV: More of the original vegetation may have been cleared, new crops are introduced. There may also be shifts in farming strategies between floodwater and dry farming, dependent on rainfall patterns. These various decisions lead to changes in the microenvironment, in terms of the different spheres, which in turns leads to the modification of the microenvironment. This is the ecological inheritance that is passed down. The cultural inheritance encompasses any knowledge of best practice farming and husbandry in this region. The next generation is faced with two choices, to employ new CNC strategies or to continue to use the ones already in place

The onsite evidence indicates barley was also present, but as discussed before, it may have come in as a weed.

At the end of the EB period, there may have been a short period of increasing aridity, as indicated by the increase of the water stress index in T01-5 (see Figure 6.1) and the complete lack of rondels (C_3 grasses; see Appendix H). This could correspond the the so-called 4.2KY event, although considering that the site continued with no apparent contraction and indeed expanded soon after, it does not seem to have had much impact. In addition, this is only one sample and may be an anamoly. No cereals were found in this layer. There were some wetland plants and dicotyledons dominated the record. The sedimentary record hints at possible flash flooding (poorly sorted sands intercalated with muds), so it may be that this particular area of the floodplain was too wet and unpredictable for growing cereal crops. There seems to be no trace of fruit phytoliths either. It is quite possible that the response to possible unpredictability of the Tigris flooding was to abandon this field in favour of ones in a different area of the floodplain.

In essence, then, there appears to be continuity of some farming practices or

CNC activities, including growing cereal crops. New crops were added including fruit, which meant further, long-term commitment to this area. There also seems to be some sort of either expansion of arable land or shifting of fields, both of which could be responses to changes either in demographics and/or in the local environment (such as soil infertility). At some point, there seems to be a shift in hydrology, which may have been caused by natural variation and to some extent human modification (for instance, deforestation in the uplands), which led to unpredictable flooding and a temporary cessation of floodwater farming. No traces of farming were found in the representative sample, however, given the evidence of site continuity and expansion, it would seem that the fields were simply moved to another area (perhaps with prior land clearance), a sort of small-scale counteractive relocation. This assumption is strengthened by the continuity of practices into the MBA, which we turn to next.

Middle Bronze Age (Figure 8.3)

Going into the MBA, there is an expansion of the site and the development of monumental architecture, which may have been used for ceremonial / ritual purposes (see Laneri *et al.* In press). There is also more evidence from onsite, including phytolith, macrobotanical remains and animal bones, to add to the picture.

T01-4 likely represents the early MBA. There are still C_4 plants, however the sedimentary record indicates that there may have been regular alluviation, showing that conditions were becoming less arid. There were also multicell jigsaws, as well as sponge spicules. The latter could indicate some areas were a little waterlogged. There is possible evidence of fruit horticulture, so it seems that this area was again being used for this purpose.

Grape epidermis multicells were also tentatively identified (Chapter 7 and Figure 7.4). The soils would have had a sand fraction as well as as silts (based on the sedimentary analysis), so it may have been well-draining enough for viticulture (although grapes can tolerate wetter conditions: Zohary *et al.* 2012). The onsite evidence, particularly the macrobotanical evidence (but also tentatively the phytolith evidence) does indicate that grapes were used onsite for

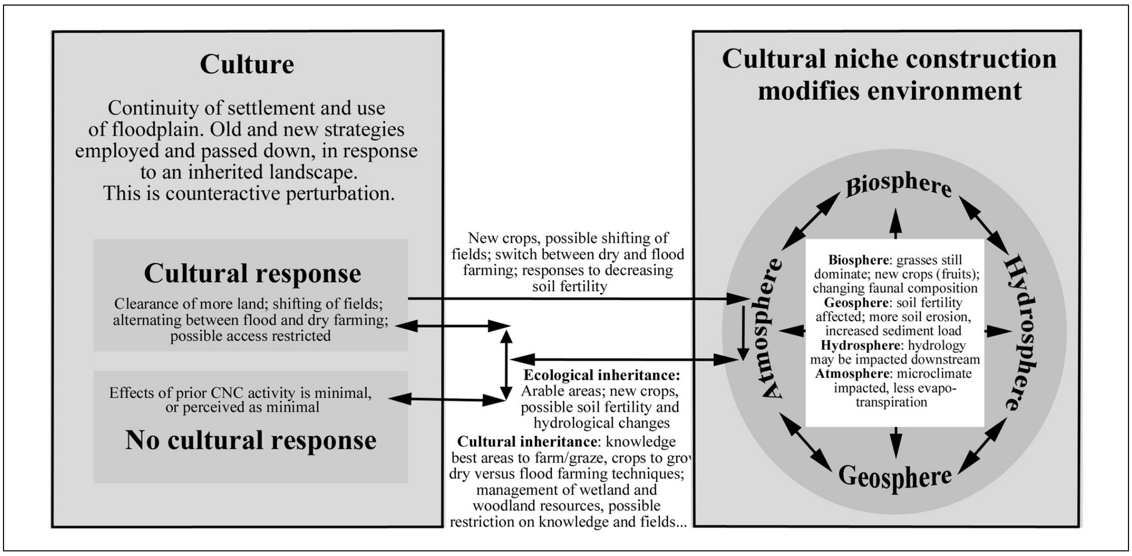

Figure 8.3: The arable niche during the MBA: There is continued use of fields on the terrace, as well as possible field rotation. Old areas are being reused for horticulture, which may be a response to changing hydrological conditions. New crops (e.g., grapes) are introduced, and there is a change in function onsite. The continuity of farming (and grazing) practices continues to modify the microenvironment and its component spheres; some strategies (e.g., field burning), may be in response to these changes. There may possibly be fields which are now restricted.

wine and/or eating. This could indicate a change in subsistence strategies. If the grape identification is correct, this leads to more questions: if the grapes were used for ritual purposes (i.e., wine, as proposed by the excavators Laneri *et al.* In press), then there is a possibility that these fields were restricted to the people associated with the ritual/ceremonial area and functions. There may have been a restriction on who owned the knowledge of viticulture and who it was passed down to, thus affecting the cultural inheritance.

G01-4a and 4c represent slightly later modification episodes. The sedimentary layer (G01-4) is comprised of fine grained sands, typical overbank deposits and indicates that alluviation was occurring. Water stress levels were also much less. Although no large multicells were found in the offsite samples, some were found onsite in contemporaneous contexts. In addition, there were also jigsaws present in both phytolith samples (G01-4a and 4c). It is unlikely that irrigation was necessary (given the evidence of alluviation), it is more likely that there was floodwater farming on this terrace.

Sample G01-4a indicates both cereal cultivation and horticulture on this part of the terrace. There may have been a small grove in the fields. Although mostly unidentified, some of the multicell cereals were wheats. Onsite, both barley and wheat were found in the phytolith and macrobotanical records, so barley must have have been grown elsewhere on the terrace.

G01-4c is very similar in terms of phytoliths but has one added feature. The sample came from a burn layer and indicates that field burning was also a strategy employed, probably to increase the fertility of the soil. This may have been a response to declining yields, but in any case, would have been knowledge passed on. Another possibility to consider for both of these layers and possibly for T01-5 is that legumes may have been grown in the fields as well. Legumes were found onsite (as macro remains). Legumes are, of course, staple crops, but they have the added bonus of being nitrogen fixers and thus help to increase fertility in soils. As such, there may have been crop rotation and polycropping as well, in order to increase soil fertility and crop yields, in addition to field burning.

In the MBA, there seems to be a continuation of EB subsistence strategies as well as the introduction of new ones, including viticulture and polycropping, as well as methods for increasing soil fertility. In addition, as discussed above, there is a possibility of new restrictions in access to fields and knowledge given the possible ritual aspect of the site.

General comments

Overall, there is a picture of initial land clearance, followed by multiple uses of the the new landscape, a combination of cereal farming and grazing, with horticulture and later viticulture. There are also hints that changing conditions, such as a shift in hydrology caused by natural and possibly anthropogenic factors, led to different strategies being employed, such as floodwater farming versus dry farming. There may have also been issues with the reduction of soil fertility resulting from the arable activity, which may have led the MBA inhabitants to employ field burning to counteract that. It seems that until circa 1782BC, the inhabitants successfully lived and 'made a living' (Ingold 1996) at Hirbemerdon Tepe. The site was then abandoned until the Late Bronze Age, but reasons for this are unclear. It does not, however, seem to be a response to changes in the environment. It seems that, based on the evidence that is available, that arable strategies were successful and adaptable and were passed on to succeeding generations.

8.2.3 Bakr Awa

Introduction

As discussed above, the dating for the Bakr Awa offsite trench is very broad and cannot be very well correlated to the onsite dataset. However, some very tentative dates for deposits were derived based on phytolith data (see Table 7.1). The CNC activities and resultant environmental modification is also speculative as the offsite data is fragmentary. There is also little environmental data from onsite, outside the phytolith record. Another caveat is that excavations are still nascent, as such all the samples come from the lower town. The excavations on the citadel have only penetrated the substantial Islamic period layers (with perhaps some late Assyrian layers in another area) (Miglus *et al.* 2013)

Early Bronze Age (Figure 8.4)

This period covers the Early Dynastic, Akkadian and Ur III contexts. As discussed in the previous chapter, both barley and wheat were found in the ED and Akkadian contexts, while only barley was found in the Ur III contexts. It is difficult to say whether this is a switch in crop preference or response to some change in climatic conditions. Tentatively, it seems that barley was more common in the samples overall than wheat, so this may have been a preference throughout the EBA. On the other hand, the Akkadian/post-Akkadian samples suggest that the barley is coming in with weeds and thus could be wild and/or used as fodder. The data is really too limited in order to draw conclusions about what was for human consumption and used as fodder.

We may, however, surmise a scenario in terms of land use. There are two other, earlier, sites in the vicinity, Tepe Murani (6500-5000BC) and Gurga Chiya

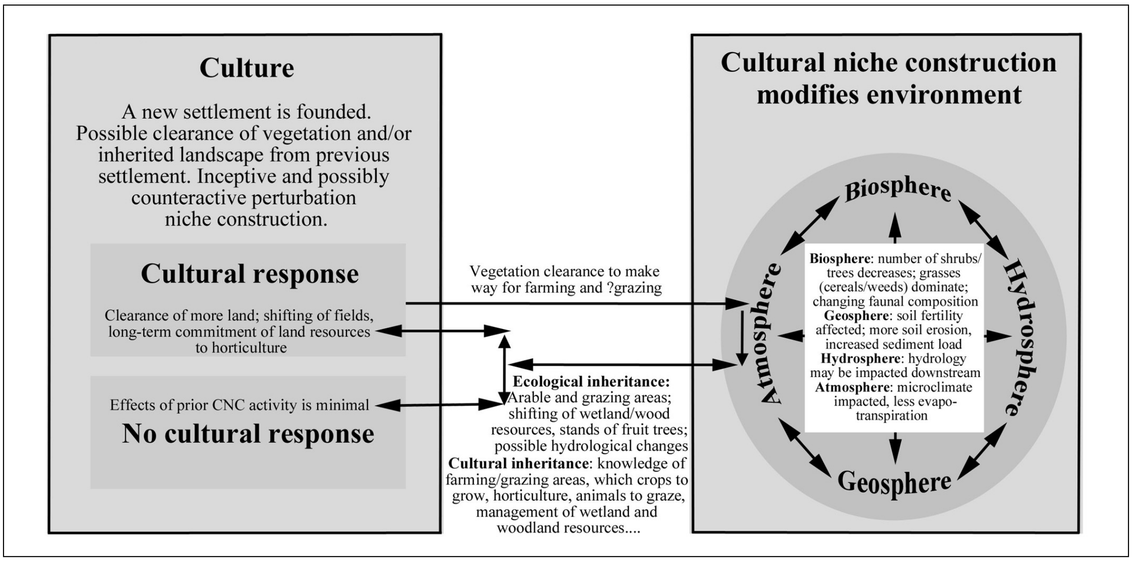

Figure 8.4: The arable niche during the EBA: There is possible land clearance to make way for arable fields and grazing areas for the inhabitants of Bakr Awa, although some areas may have already been cleared earlier. There is evidence for both cereal farming and horticulture. Land clearance and use would have impacted this niche and the component spheres, affecting the soil fertility, sedimentation, hydrology and vegetation patterns. This modified landscape would have been passed on to the next generation, along with the arable knowledge.

(4000-3000BC), which are located about a kilometre away, across the alluvial plain. It may be that these settlements used the same floodplain for cereal cultivation, although as noted elsewhere, certainly not in the immediate locale of the deep trench. At this point, this area(s) has not been located. It is possible that when Bakr Awa was first settled in the EDI (or possible earlier in the late Chalcolithic: Miglus *et al.* (2013)), they would have inherited a landscape from the earlier settlement at Gurga Chiya (and/or Bakr Awa). The site of Bakr Awa also expanded over the period of time and became more prominent with contacts in southern Mesopotamia and northern Mesopotamia. It is likely that new areas needed to be cleared for cereal cultivation. This would have taken careful thought, taking into consideration how active the channels were at this time.

The size of multicells (both of cereals and wetlands plants, which are discussed below) on the site suggests that water availability was high during this period, further suggesting either flood farming or channel irrigation, both of which necessitates that some of the farming at least occurred in the floodplain (as opposed to the terraces, for which dry farming would be indicted). Considering the sedimentary evidence discussed in Chapter 7, it seems more likely that there was flood farming at this point, and this likely continued throughout the EBA. As such, it is possible that riparian/alluvial vegetation from somewhere in the vicinity of the deep trench (where some cereal/grass phytoliths were found) was cleared away, thus modifying the landscape. The knowledge of where to farm, as well as how to farm, would have been passed down as well.

There may be hints of other crops onsite as well. Some possible fruit phytoliths were identified in most of the EBA contexts except the earliest one and the white substance found on the floor of the shrine (see discussion in Chapter 7). There are also indications of horticulture somewhere in the vicinity in the offsite samples. This could give a tentative date to the offsite layer OST1-2 a *terminus post quem* of early EBA (perhaps slightly earlier if reflecting possible horticulture at Gurga Chiya or the possible earlier settlement at Bakr Awa, for instance). Again, there is no indication where this took place, however, as discussed previously, horticulture takes a substantial commitment over years. This would also involve substantial knowledge that would be passed down through the generations.

The offsite evidence shows the modification of humans on their landscape, particularly the makeup of the vegetation in the vicinity. Sedimentation may have been affected, particularly if riparian areas were cleared as well (possibly destabilising the channel banks). However, given the activeness of the channels at this point, it is more likely that more distal areas, perhaps with open woodlands, were cleared first.

Middle Bronze Age (Figure 8.5)

During the MBA, the site expanded, with definitive structures in the lower town and finds (though no structures as yet) on the citadel (Miglus *et al.* 2013). The samples come from a substantial Old Babylonian period domestic dwelling, with rooms surrounding a pebble floor courtyard (see Figure 7.13).

From the onsite phytolith evidence, it would seem that wheat is the preferred cereal and barley is not necessarily being cultivated, or only cultivated for fodder. In addition, there are still indications of high water availability indicated by the presence of large multicells of husks and straw. The cultivation

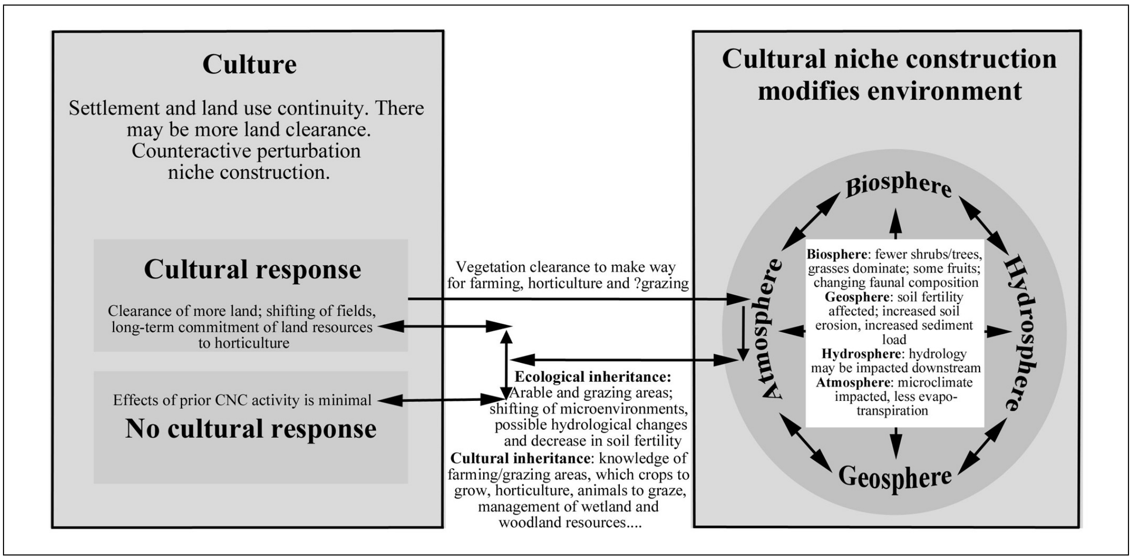

Figure 8.5: The arable niche during the MBA: There is continuation of arable practices from the EBA, but with perhaps an emphasis on wheat. Continuing use of the terrace would have impacted this niche and the component spheres, affecting the soil fertility, sedimentation, hydrology and vegetation patterns. This modified landscape would have been passed on to the next generation, along with the arable knowledge.

of cereal continued unabated, and perhaps farming methods remained largely consistent. There do not appear to be any shifts between rainfed and floodwater farming as are indicated at Hirbemerdon Tepe.

Horticulture remains important as well. Fruit phytoliths, although not particularly abundant, do make an appearance throughout the MBA. They are also present in some of the offsite contexts, indicating that horticulture continued somewhere on the floodplain.

CNC activity is difficult to discern at this point, mainly due to the lack of data and contexts. Overall, and tentatively, it would seem that cereal and fruit cultivation continued in a similar fashion. It seems that there were no major cultural responses to the modified environment, most likely because the environmental changes were not so apparent.

General comments

There seems to be relatively little change between the EB and MBA, and any impact from climate events such as the 4.2KY event, are not discernible in the sedimentary or phytolith record. It would seem that there was continuity in terms of agricultural practices and no real need for a cultural response to changing conditions. The ecological inheritance would have included changing hydrologies and sedimentation patterns but these changes may have been too small to necessitate any response. On the other hand, the cultural inheritance would have consisted of a great body of knowledge. This floodplain appears to have been prone to high magnitude seasonal flooding, which would have rendered many areas waterlogged and unsuitable for farming and horticulture, and in some cases, even grazing. The inhabitants would have had to know which areas were best for which crops. There may also have been expansion of cleared areas as the site expanded.

8.3 The wetlands niche

8.3.1 Hirbemerdon Tepe

Introduction

The evidence for the wetlands niche is again tentative, and based on the off- and onsite phytolith evidence; no macrobotanical evidence was preserved onsite. There is only one model developed for the wetlands niche (Figure 8.6, which will be used in the discussion.

Early Bronze age into the Middle Bronze Age

The offsite evidence for the early EBA (I and II) indicates that wetland plants were available to the inhabitants of Hirbemerdon Tepe. Wetland monocotyledons dominate T01-7. It is very likely that the residents of the newly-established settlement were using this resource, and perhaps managing it to some extent. A short time later (T01-7a), some vegetation had been cleared, possibly for grazing and/or farming as stated above. Wetland monocotyledons are still present, however. Although the trees and shrubs may have been cleared away from the banks, the wetland monocotyledons would have been left, as they are usually submerged in slack water areas. However, changing sedimentation patterns, arising from increased soil erosion into the channel may have had an impact on the sedges and/or phragmites (stifling their growth for instance). The offsite evidence indicates that only sedges were growing here at this point. Sedges continue to dominate the offsite record, and the onsite record for the later EBA indicates that only sedges were being used.

An area of sedges would also have made a good place for other animals and fishes, which could have been exploited, although unfortunately, there is no evidence from the site.

The dicotyledonous plants may have been reduced, but there may have been some left to exploit. However, many of the dicotyledon phytoliths could well be reflecting horticultural activities on the floodplain.

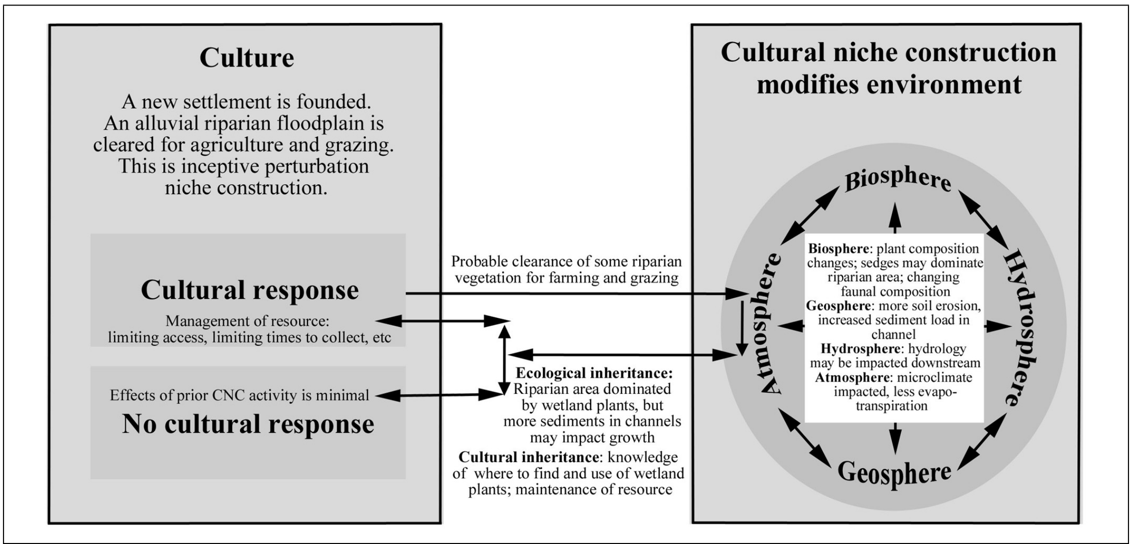

Figure 8.6: The wetlands niche during the EBA and MBA: Possible land clearance may have led to the decrease of the riparian forests but may not initially have had too much an impact on the wetland monocotyledonous plants. However, over time, increased sediments in the river may have stifled growth. The cultural inheritance may have consisted of passing on knowledge of how to use the resource, as well as how to manage it.

In the MBA phase, the offsite evidence indicates a continued presence of sedge throughout, although there does seem to be a slight decline in numbers. This however, may be a reflection on the microenvironment of the particular part of the river and floodplain (again sedimentation affecting/restricting growth), and also possibly related in part to the use of the terrace. There is also a brief appearance of *Phragmites* sp. in T01-4, in the early MBA, which may be related to the changing climatic conditions, perhaps indicating a warmer and wetter period. In the onsite record, phragmites makes an appearance throughout the MBA and going into the LBA, suggesting that Phragmites may have been more widespread in the alluvial area. However, its use is not substantial, and it may be that although an invasive species, it was not that widely available or encouraged.

The dicotyledons vary in the offsite record, but again may be reflecting more the horticultural activities (especially in T01-4) rather than any regeneration of the riparian forest.

There is also evidence of both cattle and domestic / wild pig in various contexts in the MBA period (Laneri *et al.* In press). These animals may have been kept / foraged near the wetlands area.

General comments

It is difficult to gauge the ecological and cultural inheritances in this particular niche, given the evidence to hand. However, it is likely that the modification of the arable niche (which of course 'took over' parts of the wetlands niche) had a knock-on effect on that wetlands niche. And this is the modified landscape that would have been passed on. The knowledge of how to find and use the wetlands materials would have been passed on, as well as any possible knowledge of managing this resource (including the resident animal species). Overall, there are no real trends of any decline in wetland resources, so it seems that whatever CNC responses there were, they were successful.

8.3.2 Bakr Awa

As with the arable niche, there is not much evidence to go on, but there are some interesting, if tentative trends. There is one model, which will address both the EBA and the MBA (Figure 8.7) and any CNC activity that might be discerned.

Early Bronze Age into the Middle Bronze Age

Similarly to Hirbemerdon Tepe, the sedge seems to be the wetland plant of choice to make mats, for roofing material, etc. However, there is also somewhat more usage of *Phragmites* sp. Reeds are consistently found throughout the periods covered here, albeit in smaller numbers as compared to sedges. There is also a peak in Sample 101/2232, a late third millennium floor, perhaps reed was used for floor matting, as discussed in Chapter 7. The offsite samples also show the appearance of phragmites in the phytolith record at the same time as fruit trees, in the layer (OST1-2) that was previously tentatively dated to the beginning of the ED I, i.e. the beginning of the settlement at Bakr Awa. While it is possible that there was a shift in climate which led to an increase in *Phragmites* sp. or perhaps changing channel patterns created microenvironments which were more conducive for reeds to grow, it may also be that the inhabitants encouraged stands of phragmites in this area. This is of course tentative, but tantalising nevertheless. Sedge, too, is ubiquitous throughout the temporal scale of the site, though not present in all of the samples from offsite. Of course, much has to do with preservation of multicells, which were the phytoliths considered in these graphs (it is only possible to identify genus/species of most monocotyledons through multicells).

The MBA, as with the arable niche, shows a continuation of what happened previously. However, there appears to be a decline in dicotyledon and wetlands monocotyledon phytoliths. This may have something to do with preservation issues, but there may also have been some decrease in the riparian vegetation. The onsite data appears to show a similar trend, however this seems to be more related to context. The areas with low wetland plants is the courtyard, and perhaps no matting was used there. A preserved reed mat was found in OB context room 103. In the LBA, there is continued use of wetland plants but in slightly smaller numbers. It could be that the offsite samples correspond to this later period.

An interesting side note is that there were also some very large wetland plant multicells. There is no literature on whether this can also be an indicator of increased water availability. However, it would be interesting to see what conditions could produce larger conjoined multicells in wetland plants.

General comments

Overall, there appears does not appear to be much management of wetland resources. It is difficult to say whether the presence of the phragmites is a result of human intervention, climatic conditions or accidental intervention (overex-

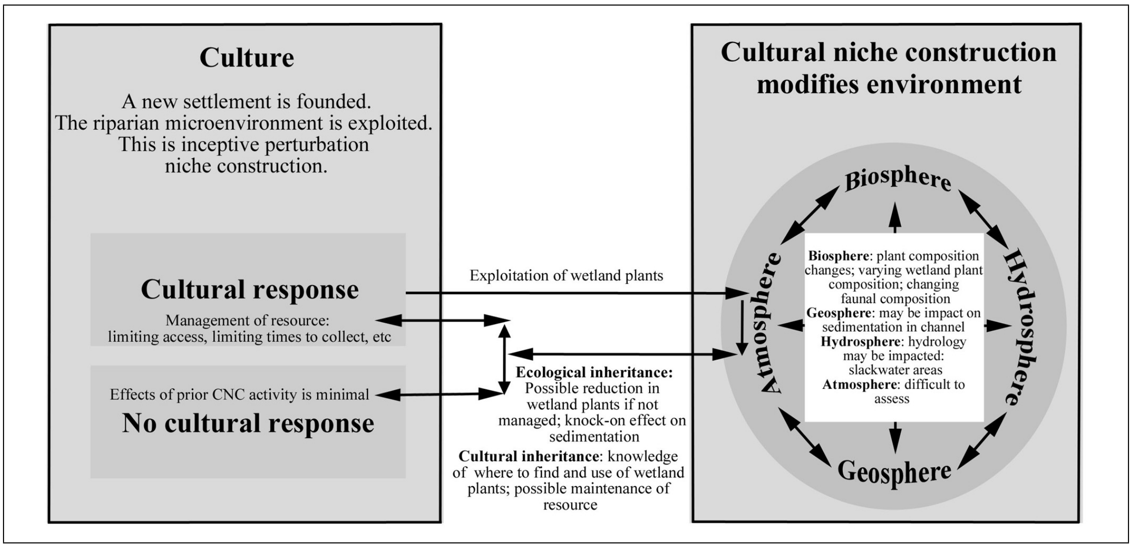

Figure 8.7: The wetlands niche during the EBA and MBA: The samples here don't really indicate land clearance. However, there could be evidence of overexploitation of wetland monocotyledons, particularly later in the record (possibly in the LBA period). Thus there don't seem to be (long-term) management strategies in place. The continued presence of these resources onsite does indicate that knowledge of the use and exploitation of these resources continued throughout the archaeological period.

ploitation of sedge leading reeds to colonise), or perhaps it is a combination of all of these factors. Given the environment of the deep trench, it is likely that there were plentiful areas of wetland plants, and given the abundance, were not really managed. The ecological inheritance may have consisted of a gradually diminishing supply of wetland plants, which later may have impacted sedimentation and hydrology in the locale (fewer slack water areas for instance). The cultural inheritance would have consisted mainly the knowledge of how to use and where to source the wetland plants. There may have even been proscribed uses, i.e., reeds for mats, sedges for baskets.

8.4 The woodlands niche

8.4.1 Hirbemerdon Tepe

Introduction

The woodlands niche discussion reflects phytolith evidence from offsite, as well as evidence from onsite, including phytoliths, macro remains and animal bones. Overall, there seems to be some sort of management of woodland resources in that there are no major flood incidents until the post-MBA period (G01-3). This is corroborated by the evidence from other parts of this region (Wick *et al.* 2003).

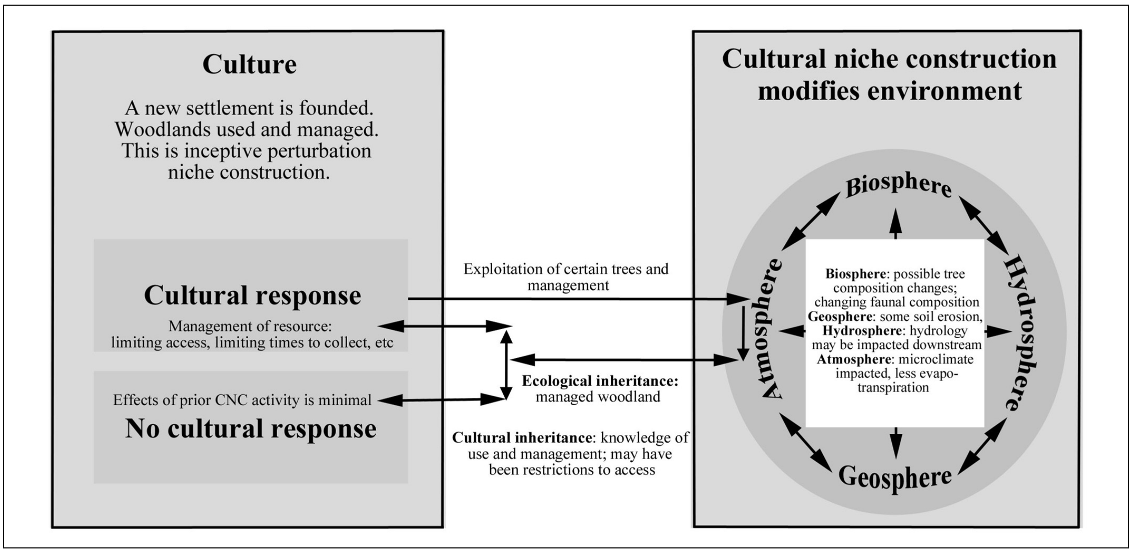

Figure 8.8: The woodlands niche during the EBA and MBA: There may have been long-term management of woodland resources, particularly since there may have been a ritualistic aspect to deer and perhaps hunting. Thus knowledge and access may have been restricted.

Early Bronze Age to Middle Bronze Age (Figure 8.8)

Unfortunately, there is little evidence for this period, so the discussion is not very detailed. The sedimentary evidence indicates regular alluviation followed by some flash flooding but this does not seem to be caused by deforestation in the uplands, but rather general overall drier conditions. It is also possible that sedimentation patterns were also slightly impacted by riparian clearances further up the river, which would have affected riverbank stability. The tree coverage index varies across the EBA as do the phytolith percentages. The onsite data indicates that there was some use of dicotyledon material. Overall, the woodlands seem to have some sort of management (or at least no large scale overexploitation), however, the vegetation clearance locally would have had an impact on the sedimentation further downstream, increasing erosion and so on.

During the MBA, the onsite evidence indicates uplands forest management; the evidence comes from a combination of phytolith, macro remains and animal bones. Timber was used as building material, as indicated by finds onsite. Charcoal was also found in the phytolith evidence. The animal bone evidence was very interesting for this time period. There were quite a few wild animals, more so than would be expected for a site from this time period (Laneri *et al.* In press). The most prevalent of these was the red deer, whose bones also were found in ceremonial / ritual contexts (Laneri *et al.* In press). Red deer's preferred habitat is open woodland. The dicotyledon phytolith evidence for offsite and onsite also contained some tentatively identified oak phytoliths (an indicator of open woodland). It is possible that upland woodlands were managed as well, in order to encourage a local population of red deer (and other game animals) and possibly for timber. This management would have not only ensured a sustainable source of timber and deer, but also would have impacted sedimentation (maintaining stability). Indeed, there is no evidence of higher magnitude flooding until some point after the MBA. It is possible that at that point, there was increased deforestation (mismanagement) leading to increasing sediment loads in the rivers and accelerated erosion.

Furthermore, given the more ritual context, it is possible that access to woodlands, resources and hunting was restricted.

General comments

Over the given period, there seem to be hints of active management of the woodlands, possible for mainly ritual reasons. The ecological inheritance of a managed woodland may not have been shared by all, and knowledge of management of and access to woodland resources also may have been restricted.

8.4.2 Bakr Awa

There is very little evidence, especially from the offsite contexts. The comments here are very tentative as a result.

Early Bronze Age to the Middle Bronze Age (Figure 8.9)

Onsite, there is some evidence for the use of woodland resources, including possible use of charcoal and timber. It is probable that this was sourced from the uplands. The sedimentary record does not indicate flash flooding, so it is conceivable that the use of timber and charcoal resources was managed. The offsite evidence probably reflects the trees/shrubs growing in the immediate vicinity, i.e., riparian growth.

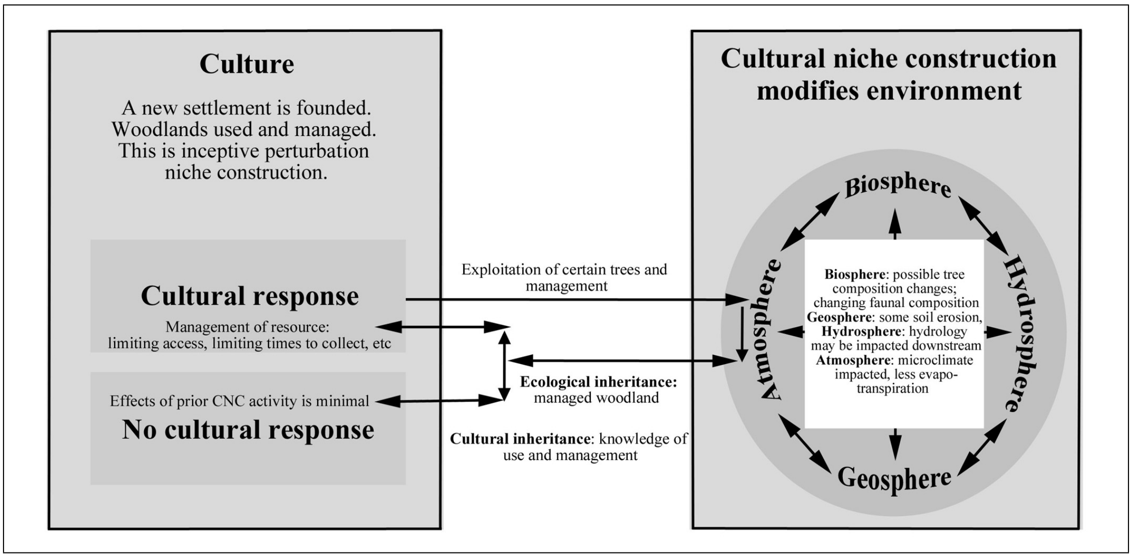

Figure 8.9: The woodlands niche during the EBA and MBA: There may have been long-term management of woodland resources, which may have had a stabilising effect on the ecology. It is not known whether there were any restrictions to access or knowledge.

The MBA has similar results in terms of counts. Only the OB courtyard shows a marked decline, but again this could be down to function of the courtyard rather than a decline in the use or availability of woodland resources. As before, there are no indications in the sedimentary record of deforestation so the management must have been consistent with fairly low key use of resources.

8.5 Concluding comments

The question of whether or not sedimentary evidence and phytolith evidence could be used together in order to elucidate on human modification of the environment and ecological and cultural inheritance as posited by cultural niche construction theory was explored in this section. The evidence was, unfortunately, very fragmentary in many cases, particularly with the Bakr Awa samples. However, there were some tentative trends that could be discerned, hints of changing strategies and responses to modified landscapes. Although the results were in some respects unsatisfactory because of the limited data, they did show that there is potential in using these datasets to explore further these issues. Indeed, there are many more offsite and onsite samples from Kurdistan that await analysis, which should help to increase the robustness of the data, and thus any interpretations.

Overall, it seems that both phytolith and sedimentary evidence, especially when used together with other available datasets, can help to understand CNC activities and to explore ecological and cultural inheritances. Indeed, the very nature of the evidence is environmental and thus should be used when attempting to describe and explain human modification of the environment, using the CNC perspective.

Chapter 9

Concluding comments and further research

9.0.1 Introduction

The research discussed in this thesis represents an evolution of an idea. I initially set out to understand more fully the relationship between societies and environmental change, particularly at the end of the third millennium in the Near East, using Hirbemerdon Tepe as the research site. The datasets first proposed included offsite sediments, the diatom record from a lake core and onsite phytolith evidence. While doing the initial desk-based assessment of Hirbemerdon Tepe, it became immediately obvious that there was no lake present, and thus a lake core sample would not be possible. A change of plans ensued which involved onsite phytolith analysis combined with offsite sedimentary analysis. However, while I was taking the offsite samples, I also decided to take some additional samples for phytolith analysis. I also subsampled from the bulk sediment samples.

The first offsite sample that I analysed was T01-6, the sample that contained the large emmer multicells, which ignited my interest in locating land surfaces and trying to discern land use strategies using offsite phytolith samples. I also began to notice that some phytoliths looked different to others, in terms of their taphonomical attributes. Some looked dissolved, while others looked as if they had been fractured and chipped. Because of my training in sedimentology and transport mechanisms and alluvial settings, as well as my experience in diatom taphonomical issues, I began to wonder if it was possible that there were two populations of phytoliths: those that had been deposited *in situ* and those that had been transported via fluvial processes from elsewhere.

In the meantime, it became clear that although Hirbemerdon Tepe was an interesting and somewhat unusual site, there would not be enough samples to test hypotheses or answer the research questions set out. Several other sites were selected for additional research and sampling, however, there were a series of problems including bureaucratic nightmares (in Turkey: we were unable to export environmental samples from another nearby site), lack of offsite contexts (in Lebanon, where the site (Sidon) was located in a large city, Saida), and unfortunately war (in Syria, where a number of sites were possible until the situation deteriorated so badly). In 2011, I was approached by Dr Mark Altaweel and Prof Karen Radner to help them on the palaeoenvironmental project in Iraqi Kurdistan. This proved to be to be exactly the type of environmental setting to explore. The area was similar and yet different enough to provide a good comparison against Hirbemerdon Tepe. Offsite and onsite contexts were both easily available. More importantly, samples could be exported with ease and the political situation was stable. The Iraqi Kurdistan project has since then expanded considerably.

The Iraqi Kurdistan project gave me the opportunity to more fully develop my initial ideas and firm up the research questions, as well as to better establish the protocol for differentiating land surfaces and the two different populations of phytoliths. It also gave me an opportunity to refine my sampling strategy, particularly in offsite contexts. Whereas Hirbemerdon Tepe was almost accidental, Iraqi Kurdistan was much better planned.

The combination of results from the two areas in southeast Anatolia and Iraqi Kurdistan, from both onsite and offsite contexts, enabled me to begin to understand the complex relationship between societies and their environment, using the framework of cultural niche construction, and using the environmental methods of sedimentary and phytolith analyses.

9.0.2 Research questions

Three research questions were advanced: (1) How are local and regional environmental changes reflected in the sedimentary and phytolith records?, (2) What resource and land use patterns can be discerned in the onsite and offsite proxy data?, and (3) How can sedimentary and phytolith evidence be used, in conjunction with other datasets, to elucidate on human modification of the environment and ecological and cultural inheritance as posited by cultural niche construction theory?. This thesis set out to answer these, using sedimentary and phytolith evidence as primary datasets. An overarching aim of this research was to show how useful these datasets are, especially when combined together and especially when looking on both on- and offsite samples.

The first question was successfully answered, despite issues of phytolith preservation in the offsite samples (an issue discussed in Chapter 5). The sedimentary evidence could have been satisfactory on its own, as it provided evidence of river behaviour, which could be explained by both climatic variation as well as human intervention or management of the environment. For instance, at Hirbemerdon Tepe, we see a general pattern of alluviation throughout the late EBA and MBA, with minor interruptions in deposition. This can be explained by possible variations in the climate system (periods of more and less precipitation) as well as management of the uplands woodlands (mass deforestation would have led to increased flash flooding episodes, which would have been evident in the sedimentary record, for instance). However, the addition of the offsite phytolith record, and to some extent, the onsite record, provided more detail. From this evidence, agricultural strategies could be discerned (such as land clearance and possible polycropping) as well as probable woodlands management, with the continued presence of dicotyledon phytoliths throughout the temporal record.

The land surface protocol developed, although still in its infancy, also helped to differentiate land surfaces and regional versus local signals in the phytolith record, which in turn enabled me to show how the environment changed over time, both locally and regionally.

The second research question, regarding resource and land use followed up from the first question. Again, although both datasets could be used to answer this question on their own, the combination of the two was far more powerful as an explanatory method. Phytolith evidence, from both on- and offsite contexts can give some information regarding agricultural strategies, however, combining it with sedimentary evidence, helps to further refine the interpretation. For example, if the phytolith evidence hints at increased water supply in the form of large conjoined multicells, it is not certain whether this is a result of floodwater farming or channel irrigation, two very different agricultural strategies, which indicate very different climatic and environmental conditions. However, with the added sedimentary evidence of, for example, regular alluviation, we can then conclude more firmly in favour of floodwater farming and increased precipitation.

The third question was perhaps, a little more tenuously answered. This was mainly due to the lack of samples as well as phytolith preservation issues. Despite this, certain niche constructing activities with resultant inheritances could be hinted at, in different niches or microenvironments. What this shows is that the combination of sedimentary and phytolith evidence should be used to address questions regarding human modification of the environment using the niche construction framework. More samples are needed, clearly, and perhaps more correlation with other datasets such as macrobotanical or faunal remains, as well as textual evidence and speleothem data (for baseline climate information). A more refined version of the land source protocol developed here would also help: we would be able to distinguish regional signals from local signals and thus better understand niche constructing activities taking place locally versus those taking place elsewhere, such as in upland forests.

9.0.3 Benefits of the research and methods

As mentioned above, the combination of phytolith and sedimentary evidence provides us with a powerful dataset that enables us to better understand how humans modify the environment. By modifying the environment, I do not only mean the detrimental effects of mass deforestation, for instance, but also sustainable management of various resources such as wetland plants and woodlands, as well as agricultural strategies that can be discerned in the offsite and onsite records.

As far as I know, this is the first time that both methodologies have been combined in this way, to answer these types of research questions, particularly those addressing land use. Offsite samples seem to be used more to address questions regarding broad environmental change, which may or may not be (at least partially) caused by human modification and activity. However, I have not come across any research that tries to locate those areas for farming, grazing and other activities, which can then be tied to a particular site at a particular time. This is a very important aspect in trying to understand site economies, subsistence strategies, cultural change and many other research questions, as it sheds light on where and how people used their environments.

Moving from the broad concepts to more specific socio-ecological questions, these methods and the theoretical framework of cultural niche construction also enable us to understand and explain cultural change in the Near East during the third and second millennia. As discussed elsewhere, there has been much debate regarding cultural change, contraction, expansion, abandonment, and so, on, particularly at the end of the third millennium. There have been attempts to extrapolate evidence of cultural and environmental change from one region (such as southern Mesopotamia or the Khabur region) and apply it to others. There has also been much discussion of how people adapted to the changing environment. What the research presented in this thesis shows is that first, we need to understand what is happening in a particular area, and that what is happening may or may not be similar to other regions. We need to look at the local scale evidence, environmental and cultural. Even if the climate is changing, and becoming generally more arid, for example, this does not mean that the effects of increasing aridity will be uniform across the Near East. Much depends on local conditions: precipitation patterns, topography, orographic position, vegetation cover, and, of course people. And this leads to the second point of this research: people do not simply adapt to a changing environment, they are actively changing their environments and as such adapt that environment as much or more so that adapt to it. These modifications can lead to environmental change, which will also be seen in the local proxy records. And there will also be cultural change as a result of these modifications and of course, the inheritances – ecological and cultural – that are passed on to succeeding generations. Cultural niche construction is an excellent way of visualising and explaining this dynamic relationship between people and their landscapes, and how this changes over time through passed on knowledge and modified environments. This is especially useful when trying to explain cultural change in this region during the Early to Middle Bronze Age transition.

9.0.4 Future work

There is much work to be done, both in terms of refining the land surface protocol developed here, and also in terms of the research potential in Iraqi Kurdistan.

The protocol, to determine land surfaces and distinguish between regional and local phytolith signals needs much improvement. In this thesis, it is only initially proposed, and as such, conclusions based on it are still very tentative. There are two main aspects to the land surface protocol: (1) distinguishing land surfaces in sedimentary layers and (2) differentiating between regional and local phytolith signals. A protocol for distinguishing between land surfaces and B horizons was set out in Chapter 5, however, there is a lot of overlap, particularly when dealing with more clayey strata. One criterion that could be examined is the assemblage of the types of phytoliths. It seems logical that not all phytoliths would migrate down the profile – for instance, longcells may find it more difficult than roundels, due to their shape – so it is likely that B horizons would generally be less representative than land surfaces. However, the land surface needs to be one that was subjected to rapid burial to ensure better preservation of the phytolith assemblage. This would be more likely in alluvial settings where there is regular alluviation, such as Hirbemerdon Tepe.

In terms of differentiating regional and local phytoliths, a method, based on morphometrics, for instance, may be the way forward to refine and make it more scientifically robust. Firstly, phytoliths exhibiting fracturing and hollowing out need to be recorded separately from the phytoliths which seem to be only dissolved and those which seem to have suffered very little in the way of dissolution or fracturing. Secondly, measurements of the hollowing out could be taken, and compared against standard measurements, which would help to indicate transport distance and velocity of water. This has been done with other sedimentary clasts (particularly with glacial deposits, see: Benn and Evans 2010), so there is no reason to assume that it is not possible with these silica clasts.

Establishing a more rigorous approach in this protocol could go a long way in addressing questions regarding land and resources use, short-term and long-term environmental change. It may well help to differentiate human 'impact' from natural climatic and environmental variation.

The site in Turkey, as mentioned in the text, is now closed and will be inundated once the Ilisu dam project is completed. However, the research in Iraqi Kurdistan is only beginning and there is much work to be done, and the potential for even further research. The political situation is now, of course, a little shaky in the region, and although Suleimaniyah province is safe and stable at the moment, we do not know what will happen in the next few months. However, there are a number of cores and bulk samples from different areas in the Shahrizor that await both geoarchaeological and phytolith analyses. These analyses will add to the picture that is already emerging as well as give me a chance to further refine the land surface protocol. In addition, there are two speleothems that have been collected from cave sites for analysis. The first one, from Kuna Ba, was discussed briefly in the text, and covers the late Holocene to modern period. There is also another speleothem from the same cave, which awaits dating and analysis by Prof David Mattey. Hopefully this speleothem will cover an earlier period of the Holocene, which will then in turn provide much needed local baseline climate data. In the meantime, cave monitoring is being carried out by local geologists, and we are planning a caving expedition in February to collect more speleothems, dependent of course on the political situation.

In the mean time, it is hoped that this research shows, firstly, how important it is to obtain and use local proxy data where possible when addressing questions regarding the human-environmental relationship in all of its complexities. Secondly, this research shows how useful both sediments and phytoliths are in providing evidence for environmental change, resource and land use, and human environmental modification. Using these proxies together, in the framework of cultural niche construction theory, enables us to better understand how our ancestors really did live and 'make a living'.

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APPENDICES

Appendix A

Field recording forms

Stratigraphy recording form

Country ______________ Project ________________________
Described by ______________ Date ________________________
Trench number or description ____________________________
Location near __________________
UTM Grid ______________ X ______________ Y ______________
Latitude ________ Longitude ________ E ________ N __________
Elevation ________ Height ________ Width ________
Type (tick): Cut ___ Trench ___ Core ___ Other __________________
Illustration/stratigraphic log? ___ Reference number(s) ______________
Photograph? ___ Reference number(s) ________________________
Remarks ____

Unit _____ Depth ________ Length ____________ Colour ____________________
Sample? ___ Sediment ______________ Number ____________
___ Diatom ___ Sample no(s) ______________________________
___ Phytoliths ___ Sample no(s) ______________________________
___ C14 ___ Sample no(s) ______________________________
___ OSL ___ Sample no(s) ______________________________
Duplicate(s)? ______________________________________
Colour (wet) ____________________ (dry) ____________________
Grain size ____________________ Sorting __________________
Roundness/Sphericity ____________________ Consistence ____________________
Composition ____
Diagnostic features ______________________________________
Remarks ____

Unit _____ Depth ________ Length ____________ Colour ____________________
Sample? ___ Sediment ______________ Number ____________
___ Diatom ___ Sample no(s) ______________________________
___ Phytoliths ___ Sample no(s) ______________________________
___ C14 ___ Sample no(s) ______________________________
___ OSL ___ Sample no(s) ______________________________
Duplicate(s)? ______________________________________

Colour (wet) ____________________ (dry) ____________________
Grain size ____________________ Sorting __________________
Roundness/Sphericity ____________________ Consistence ____________________
Composition ____
Diagnostic features ______________________________________
Remarks ____

Figure A.1: Form used to describe sediments in the field and lab, using a number of parameters

Sample log

Country ________________ Site __________________________

Sample no. _________ Unit ______________
Description ____

Sample no. _________ Unit ______________
Description ____

Sample no. _________ Unit ______________
Description ____

Sample no. _________ Unit ______________
Description ____

Sample no. _________ Unit ______________
Description ____

Sample no. _________ Unit ______________
Description ____

Sample no. _________ Unit ______________
Description ____

Sample no. _________ Unit ______________
Description ____

Sample no. _________ Unit ______________
Description ____

Sample no. _________ Unit ______________
Description ____

Sample no. _________ Unit ______________
Description ____

Sample no. _________ Unit ______________
Description ____

Sample no. _________ Unit ______________
Description ____

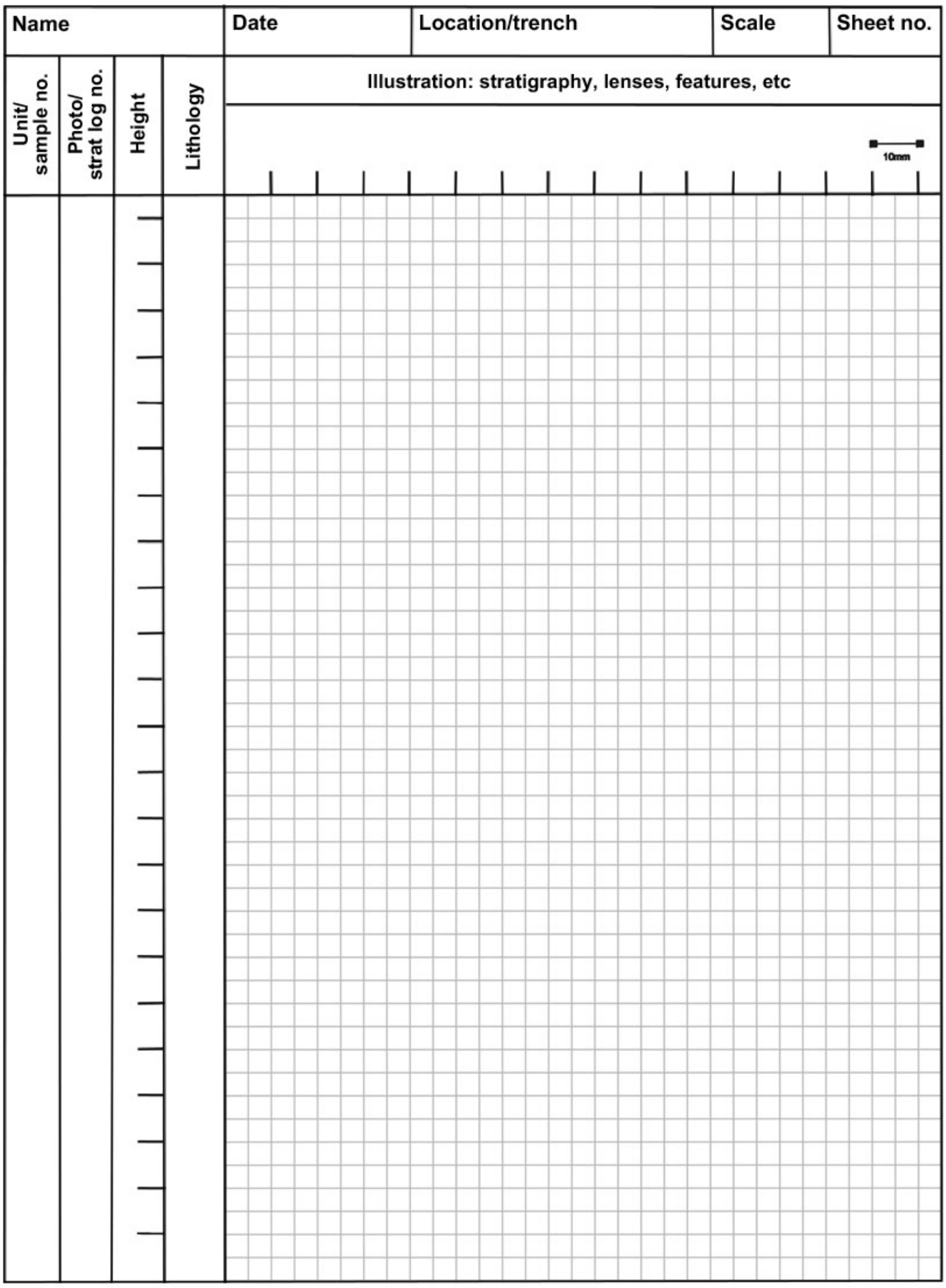
Sample no. _________ Unit ______________
Description ____

Sample no. _________ Unit ______________
Description ____

Sample no. _________ Unit ______________
Description ____

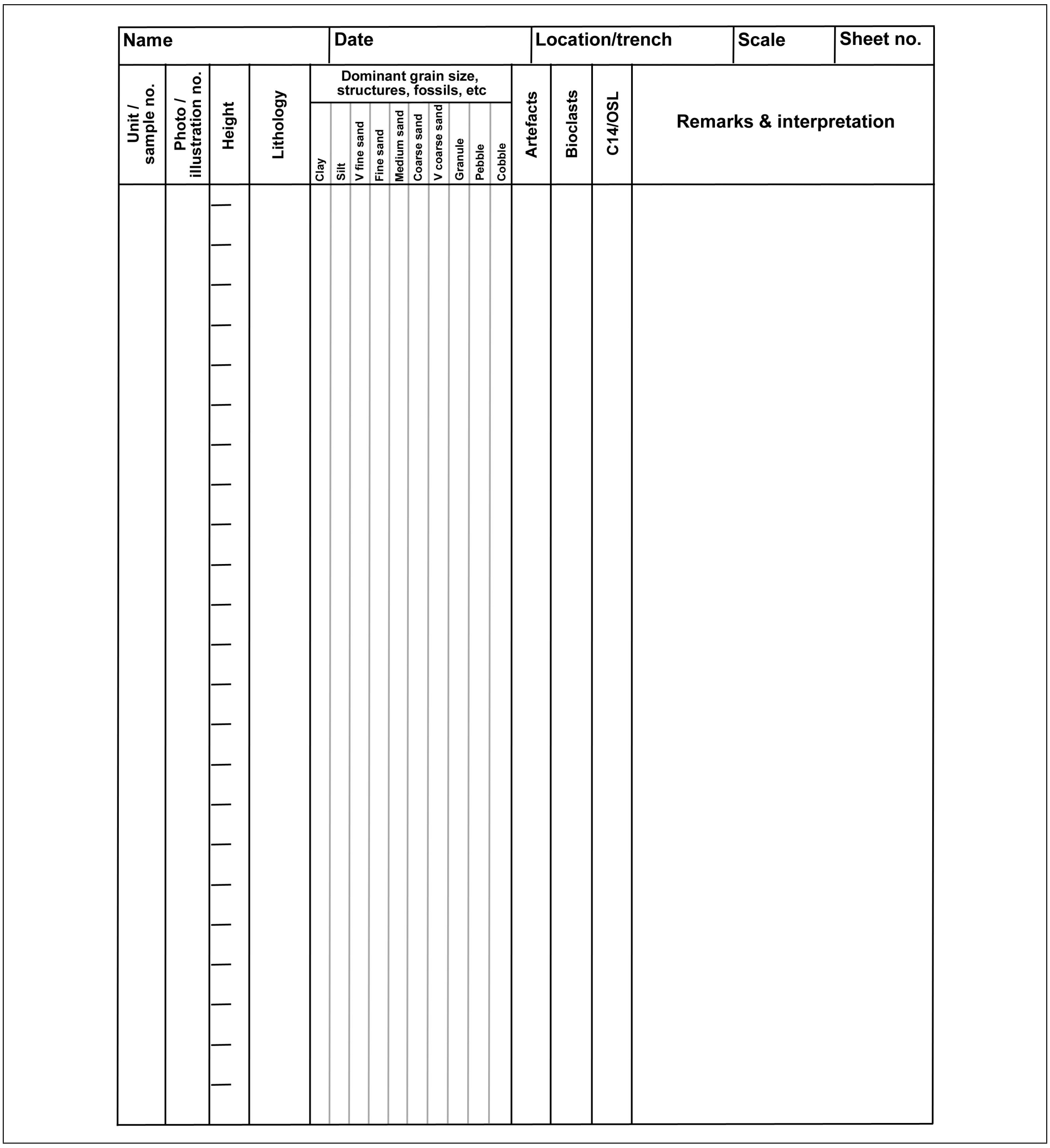
Sample no. _________ Unit ______________
Description ____

Figure A.2: Form used to log all samples for laboratory use as well as customs permissions



Name
Date
Location/trench
Scale
Sheet no.
Unit/ sample no.
Photo/ strat log no.
Height
Lithology
Illustration: stratigraphy, lenses, features, etc
10mm

Figure A.3: Form used to draw sections and record sampling locations and features



Name																		
Date																		
Location/trench																		
Scale																		
Sheet no.																		

Unit / sample no.	Photo / illustration no.	Height	Lithology	Dominant grain size, structures, fossils, etc											Artefacts	Bioclasts	C14/OSL	Remarks & interpretation
				Clay	Silt	V fine sand	Fine sand	Medium sand	Coarse sand	V coarse sand	Granule	Pebble	Cobble					

Figure A.4: Form used to record grain size of sections in the field

Appendix B

Sediment analysis – statistical formulae and results for Hirbemerdon Tepe

B.1 Formulae

B.1.1 Stoke's Law on Settling

$$V = CD^2$$

(in cm/sec), where C = constant equal to $(ps - pf)g/18\mu m$; D = diameter of particles in cm; and V = velocity

B.1.2 Mean size

$$Mz = (\phi 16 + \phi 50 + \phi 84)/3$$

B.1.3 Standard deviation

$$\sigma 1 = [(\phi 84 - \phi 16)/4] + [(\phi 95 - \phi 5)]/6.6$$

B.1.4 Skewness

$$SK1 = \frac{\phi 16 + \phi 84 - (2\phi 50)}{2(\phi 84 - \phi 16} + \frac{\phi 5 + \phi 95 - (2\phi 50}{2(\phi 95 - \phi 5}$$

B.1.5 Kurtosis

$$Kg = (\phi 95 - \phi 5)/[2.44(\phi 75 - \phi 25)]$$

B.2 Results on the sediment samples from Hirbemerdon Tepe

Sample	depth	Date	Mean (M_z)	Interpretation	Standard deviation	Interpretation
HT08-T01-2			2.9	fine sand	3.01	very poorly sorted
HT08-T01-4			4.37	coarse silt	2.83	very poorly sorted
HT08-T01-5			3.37	muddy sand	4.06	extremely poorly sorted
HT08-T01-6			3.97	coarse silt	1.31	poorly sorted
HT08-T01-7			4.37	coarse silt	2.96	very poorly sorted
HT08-T01-11			3.97	coarse silt	2.03	very poorly sorted
HT08-G02-3			5.6	medium silt	4.28	extremely poorly sorted
HT08-G02-4			5.1	medium silt	3.47	very poorly sorted
HT08-G02-9			5.17	medium silt	3.35	very poorly sorted
HT08-G01-2a			5.4	medium silt	4.13	extremely poorly sorted
HT08-G01-3a			9	clay	5.51	extremely poorly sorted
HT08-G01-4a			5.97	medium silt	2.51	very poorly sorted

Sample	depth	Date	Skewness	Interpretation	Kurtosis	Interpretation
HT08-T01-2			0.49	very positive (fine skewed)	4.57	extremely leptokurtic
HT08-T01-4			0.41	very positive (fine skewed)	2.25	very leptokurtic
HT08-T01-5			0.79	very positive (fine skewed)	4.71	extremely leptokurtic
HT08-T01-6			0.47	very positive (fine skewed)	1.86	very leptokurtic
HT08-T01-7			0.64	very positive (fine skewed)	2.95	very leptokurtic
HT08-T01-11			0.48	very positive (fine skewed)	3.02	extremely leptokurtic
HT08-G02-3			0.65	very positive (fine skewed)	2.53	very leptokurtic
HT08-G02-4			0.55	very positive (fine skewed)	1.6	very leptokurtic
HT08-G02-9			0.55	very positive (fine skewed)	1.43	leptokurtic
HT08-G01-2a			0.54	very positive (fine skewed)	1.96	very leptokurtic
HT08-G01-3a			0.53	very positive (fine skewed)	1.27	leptokurtic
HT08-G01-4a			0.1	positive (fine) skew	1.2	leptokurtic

Appendix C

Sediment descriptions

C.0.1 Terrace trench section (T01)

Unit	Depth (cm from top)	Sediment type	Colour	Sorting	Depositional environment	Comments
T01-1	52-80	Very fine sands	Pale brown (10yR 6/3)	moderate	Floodplain	Massive structure below; top cross stratified sands
T01-2	80-85	sands with granules	brown (10YR 5/3)	poor	floodplain (?flooding)	massive structure; sampled
T01-3	85-130	fine grained sands	brown (10YR 5/3)	moderate	floodplain	massive structure with sme laminations of cross stratified sands
T01-4	130-145	muds	dark greyish brown (10YR 4/2)	very poor	Floodplain	with intercalations of fine grained sands; sampled
T01-5	145-150	Very fine sands	brown (10YR 4/3)	poor	Floodplain	Massive structure; sampled
T01-6	150-193	Muds with some sands	dark greyish brown (2.5Y 4/2)	poor	Floodplain	Sampled
T01-7	193-215	very fine grained sands	olive brown (2.5Y 4/3)	poor	Floodplain	Mostly massive structure, but with some cross stratification and mud laminations; sampled
T01-8	215-218	Fine sands	light olive brown (2.5Y 5/3)	poor	Floodplain	Coarser and darker sediments
T01-9	218-230	Very fine sands	yelowish brown (10YR 5/4)	moderate	Floodplain	Cross stratified
T01-10	230-235	fine sands	light yellowish brown (2.5Y 6/3)	moderate	Floodplain	Coarser and darker sediments
T01-11	235-340	very fine sands	olive brown (2.5Y 4/3)	poor	Floodplain	Cross stratification with mud laminations; sampled
T01-12	340+	Very fine sands	yelowish brown (10YR 5/4)	moderate	Floodplain	Massive sands, with some mud laminations; lower section of the layer not reached

C.0.2 Terrace edge section G01

Unit	Depth (cm from top)	Sediment type	Colour	Sorting	Depositional environment	Comments
G01-2	30-90	muds	Light brown (7.5YR 6/3)	poor	floodplain	Massive structure; boundary not always visible; sampled
G01-3	90-190	muds	Pinkish grey (7.5YR 7/2)	poor	Flood layer	muds with larger inclusions of pebbels, rocks and artefacts; sampled
G01-4	190+	fine grained sands	Brown (7.5YR 5/2)	poor	floodplain	a few pebble inclusions; bottom of section not visible

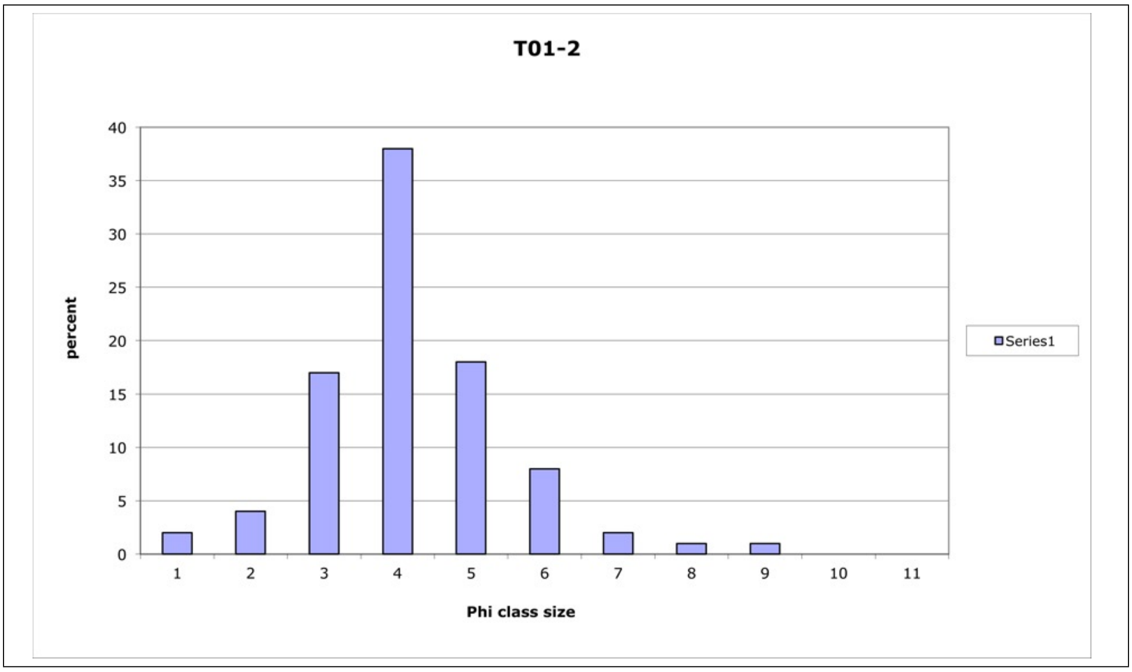
C.0.3 Terrace edge section G02

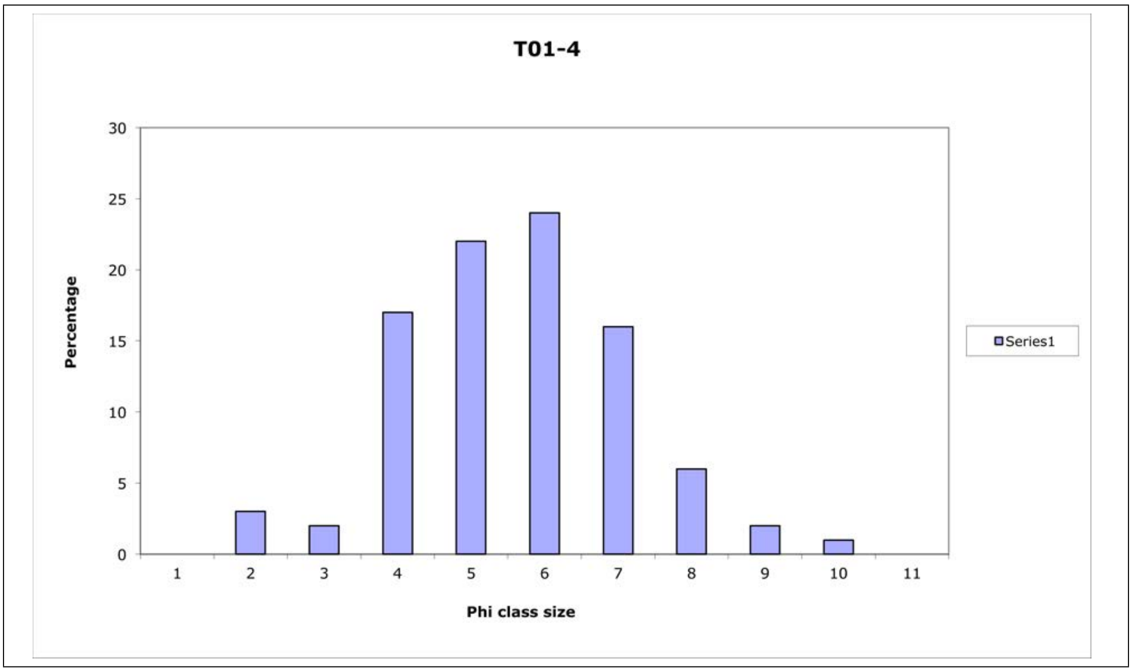
Unit	Depth (cm from top)	Sediment type	Colour	Sorting	Depositional environment	Comments
G02-1	10-23 cm	muds	Pale brown (10YR 6/3)	poor	floodplain	muds with some coarser inclusions
G02-2	23-41	sandy silts	Pale brown (10YR 6/3)	poor	Floodplain	
G02-3	41-64	muds	Light olive brown (2.5Y 5/3)	poor	floodplain	
G02-4	64-104	Fine sands	Pale brown (10YR 6/3)	poor	floodplain	Fine sands with laminations of granules and muds
G02-5	104-116	muds	Light yellowish brown (10YR 6/4)	poor	floodplain	finely laminated muds and sands
G02-6	116-120	sands	Pale brown (10YR 6/3)	poor	floodplain	fine sands with intercalated muds
G02-7	120-128	muds	Light yellowish brown (10YR 6/4)	poor	floodplain	muds with sand laminations
G02-8	128-180	Fine sands	light yellowish brown (2.5Y 6/3)	poor	floodplain	planar laminated sands with mud intercalations
G02-9	180-219	sands	brown (10YR 5/3)	poor	floodplain	poorly sorted sands and granules with intercalated muds; massive structure; sharp boundary
G02-10	219+	muds	Pale yellow (2.5Y 7/2)	poor	floodplain	muds with intercalated sands

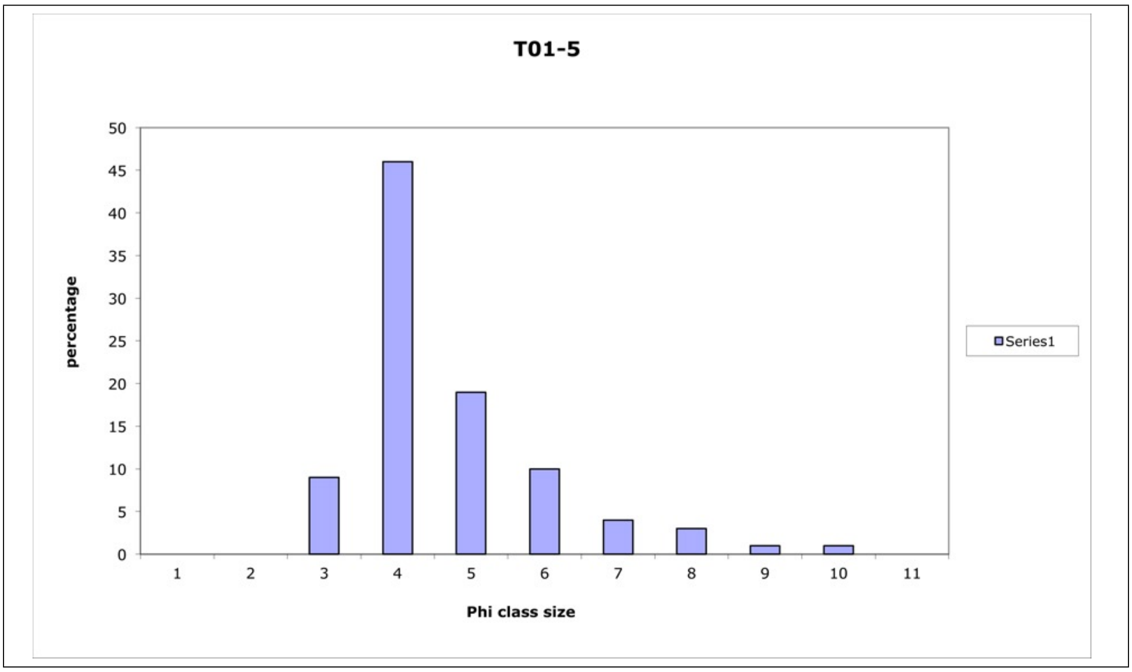
Appendix D

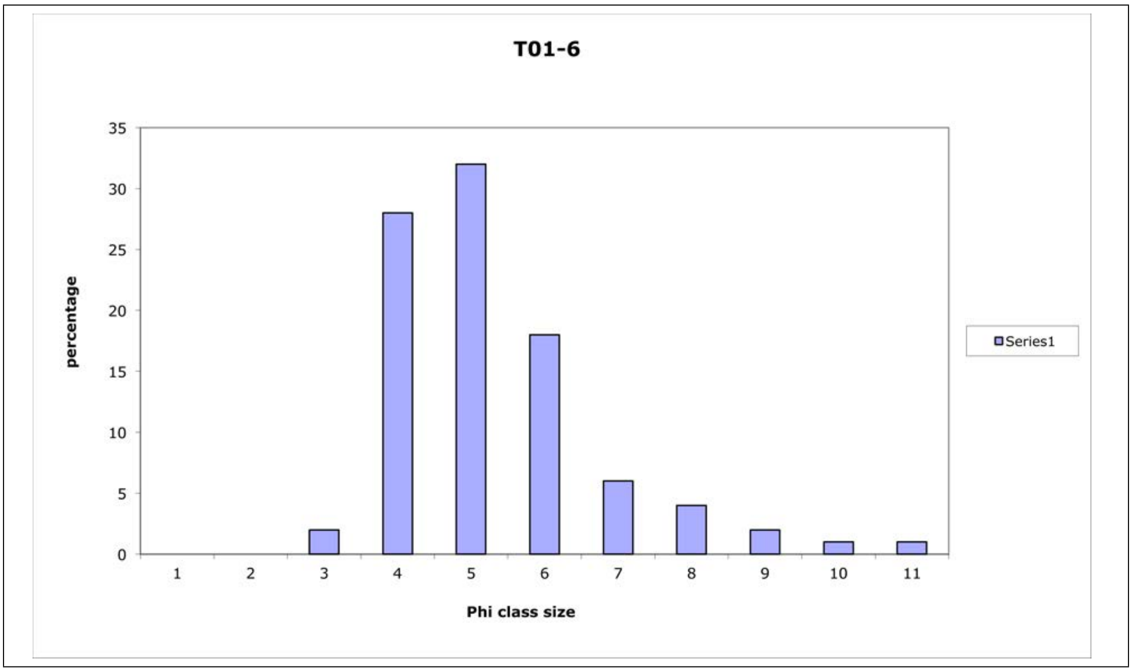
Sediment grain size histograms (Hirbemerdon Tepe)

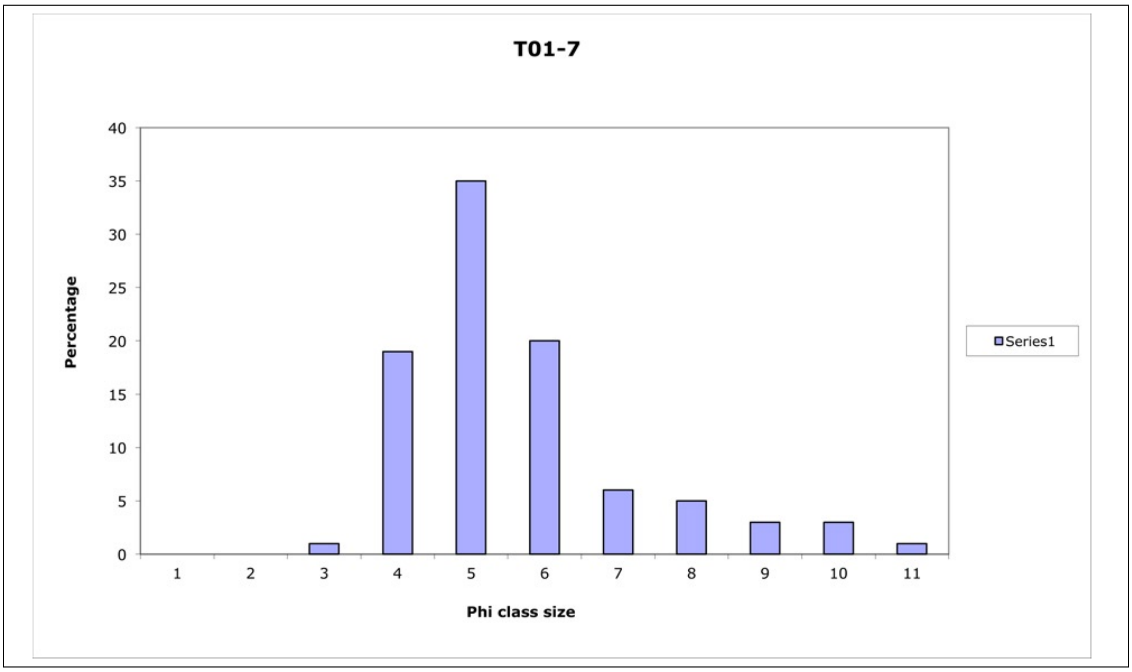
D.1 Terrace trench histograms

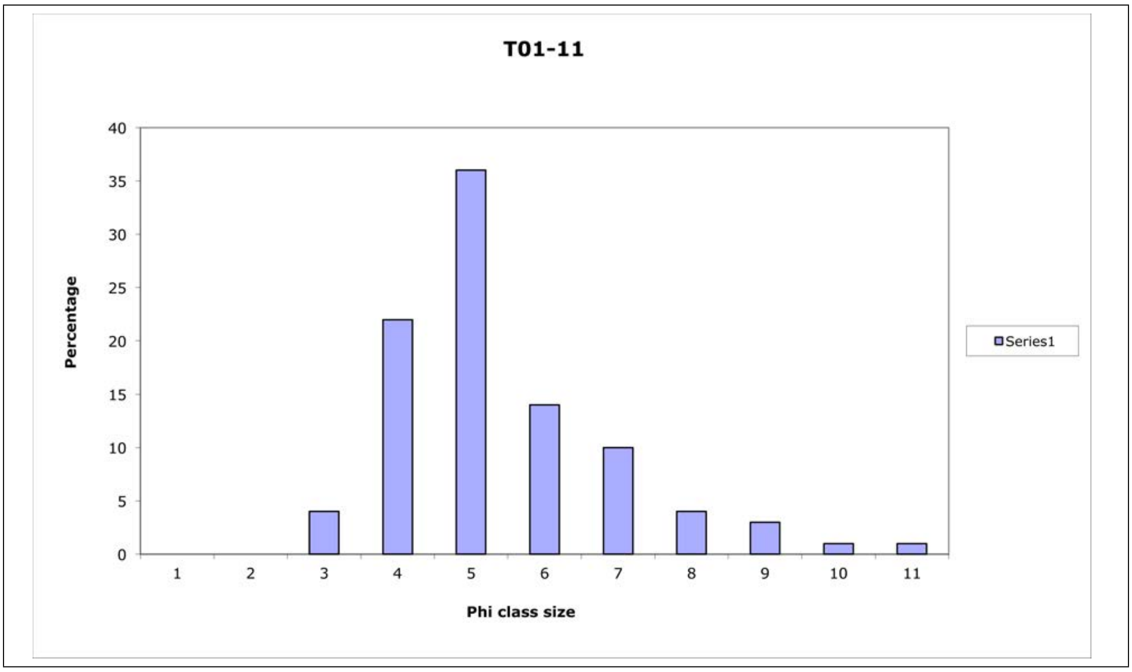



T01-4
Percentage
Phi class size
Series1
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
11

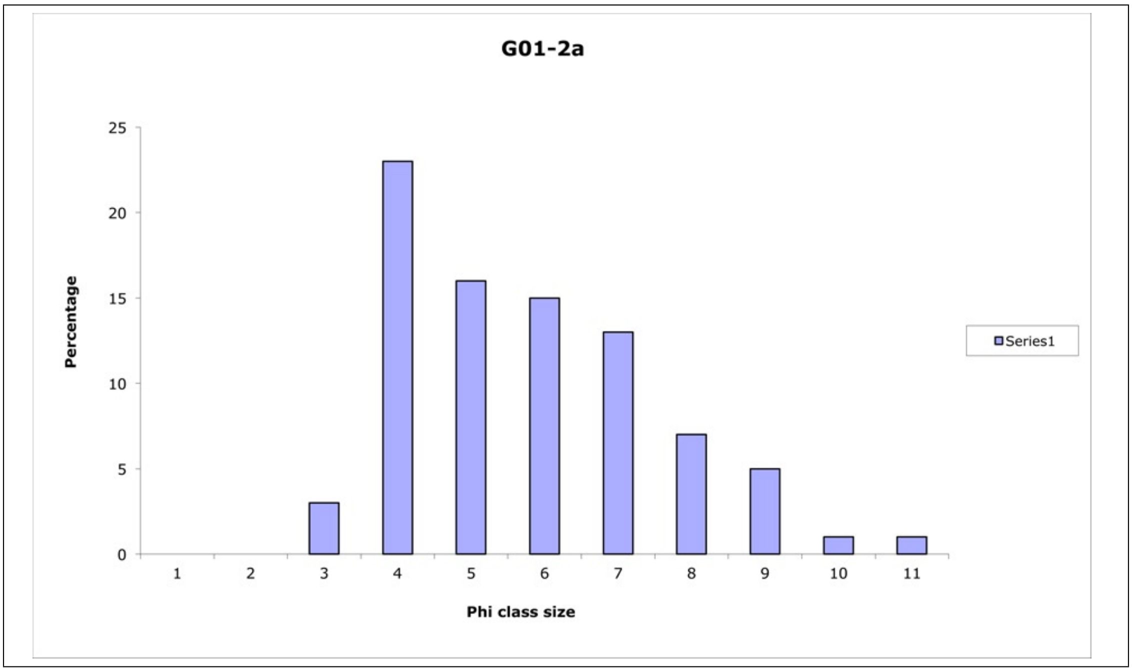

T01-5
percentage
Phi class size
Series1
50
45
40
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
11

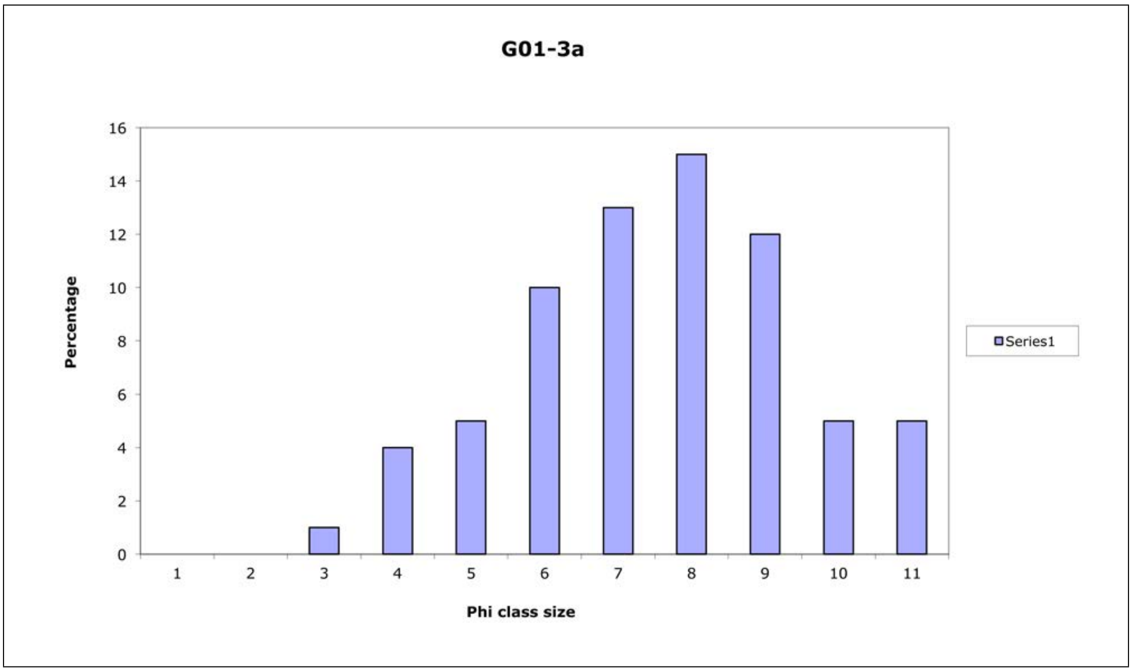

T01-6
percentage
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
11
Phi class size
Series1

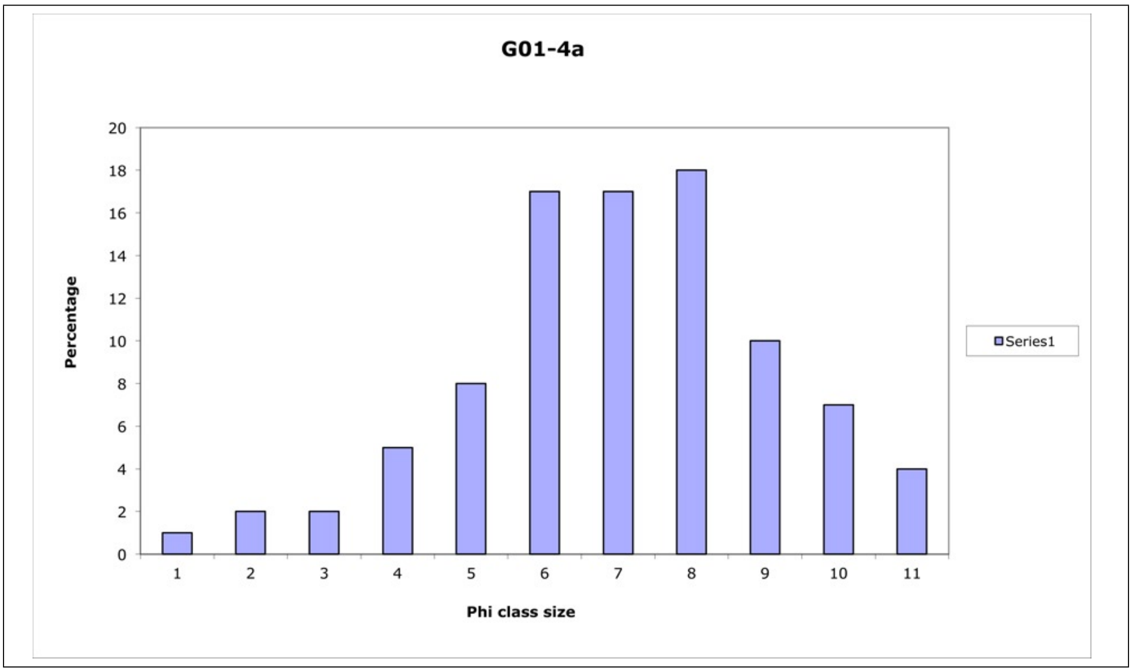

T01-7
Percentage
40
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
11
Phi class size
Series1



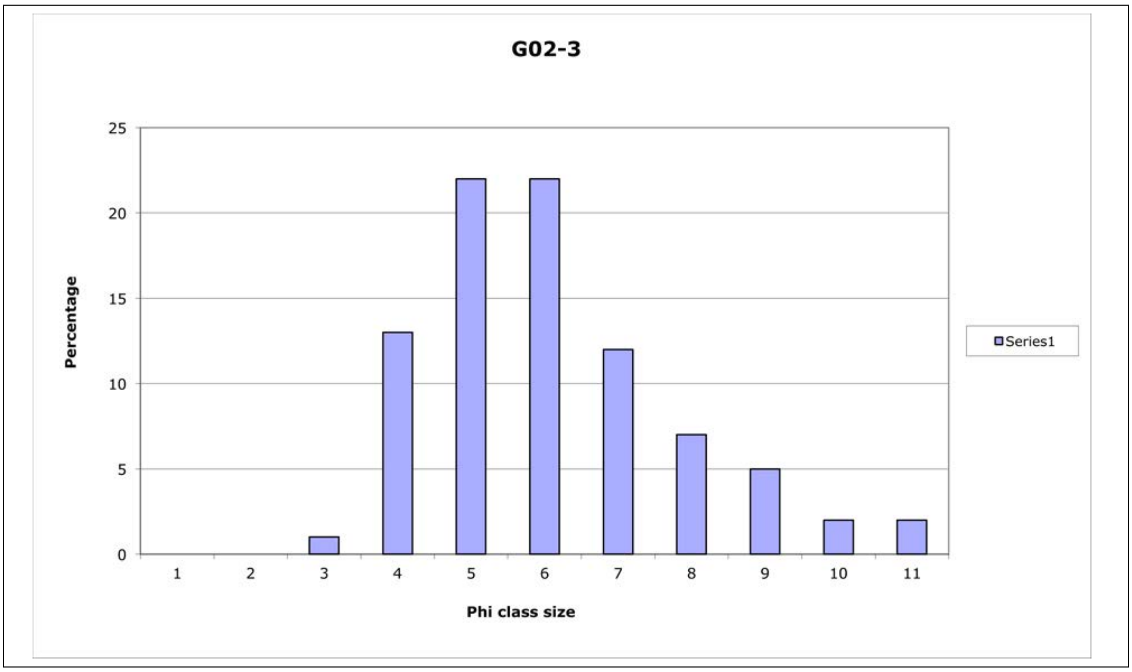
D.1.1 Terrace edge section G01 histograms

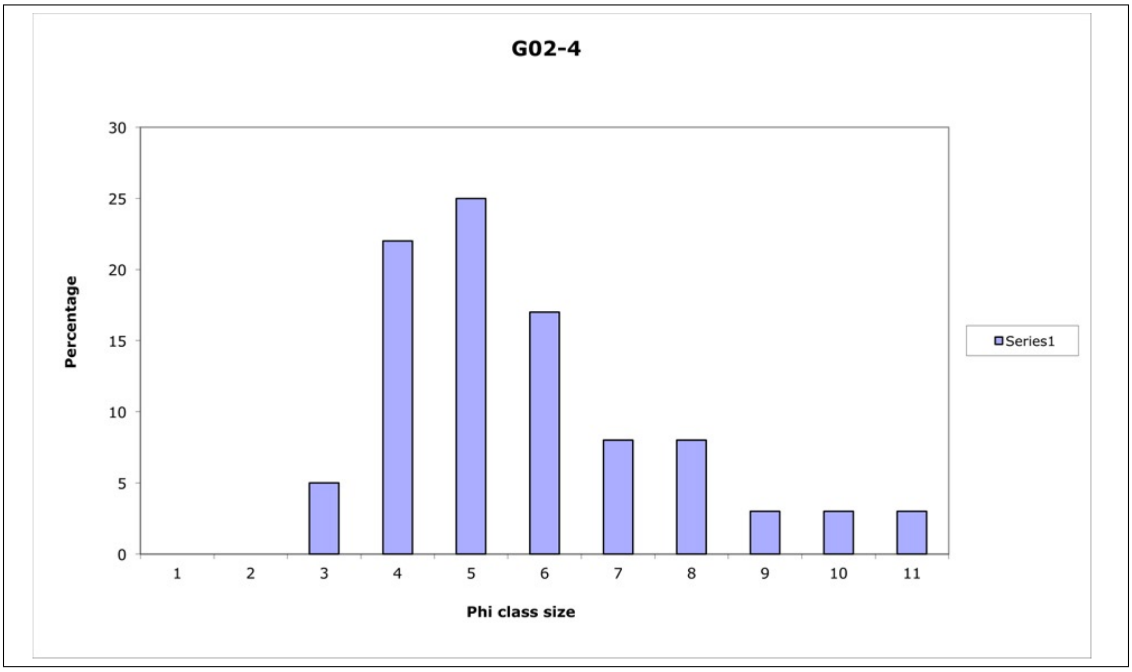


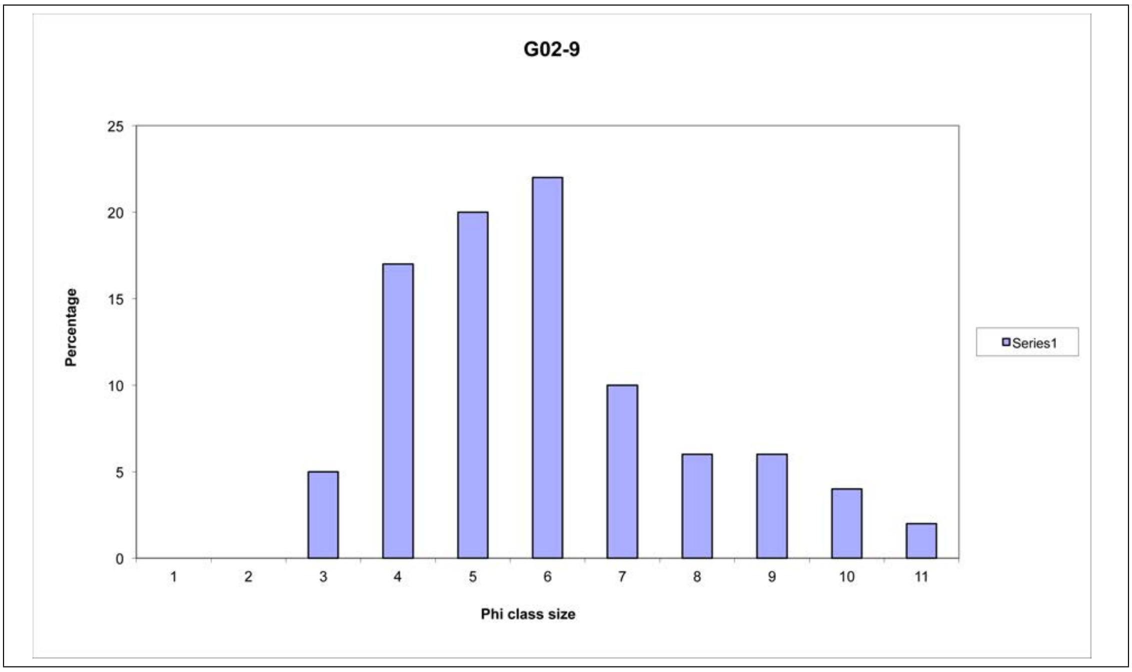

G01-3a
Percentage
16
14
12
10
8
6
4
2
0
1
2
3
4
5
6
7
8
9
10
11
Phi class size
Series1


G01-4a
Percentage
20
18
16
14
12
10
8
6
4
2
0
1
2
3
4
5
6
7
8
9
10
11
Phi class size
Series1

D.1.2 Terrace edge section G02 histograms






G02-9
25
20
15
10
5
0
Percentage
1
2
3
4
5
6
7
8
9
10
11
Phi class size
Series1

Appendix E

Sediment analyses raw data and results (Hirbemerdon Tepe)

E.1 Grain size analysis raw data

E.1.1 Hydrometer readings

Sample	Time	Elapsed time	Temp ©	Reading	Corr Factor	Corr reading	Cum % coarser	Phi class	Hydro no.	Comments
HT08-T01-7	9.31	30 sec	15	10	1.5	8.5		3.8	050386	
	9.31	45 sec		10		8.5		4.1		
	9.32	1 min		9		7.5		4.3		
	9.33	2 min		9		7.5		4.8		
	9.36	5 min		8		6.5		5.5		
	9.46	15 min	15.5	6.5		5		6.3		
	10.01	30 min	16	6.5	1.5	5		6.7		
	10.31	60 min		5		3.5		7.2		
	11.31	120 min	17	5	1	4		7.7		?
	1.31	240 min	18.5	4.5	1	3.5		8.2		
	5.31	480 min	20.5	4	0.5	3.5		8.7		
	9.01	1440 min	15.5	5	1.5	3.5		9.5		restarted
HT08-T01-11	9.38	30 sec	15.5	7	1.5	5.5		3.8	050386	
	9.38	45 sec		7		5.5		4.1		
	9.39	1 min		7		5.5		4.3		
	9.40	2 min		7		5.5		4.8		
	9.43	5 min		6.5		5		5.5		
	9.53	15 min		5.5		4		6.3		
	10.08	30 min	16	5	1.5	3.5		6.7		
	10.38	60 min		4		2.5		7.2		
	11.38	120 min	17	4	1	3		7.7		?
	1.38	240 min	18.5	3.5	1	2.5		8.2		
	5.38	480 min	20.5	4	0.5	3.5		8.7		?
	9.03	1440 min	15.5	4	1.5	2.5		9.5		restarted
HT08-G02-9	9.45	30 sec	15.5	13	1.5	11.5		3.8	050386	
	9.45	45 sec		13		11.5		4.1		
	9.46	1 min		13		11.5		4.3		
	9.47	2 min		13		11.5		4.8		
	9.50	5 min		12		10.5		5.5		

Sample	Time	Elapsed time	Temp ©	Reading	Corr Factor	Corr reading	Cum % coarser	Phi class	Hydro no.	Comments
HT08-G02-9 con't	10.00	15 min	16	11	1.5	9.5		6.3		
	10.15	30 min		10		8.5		6.7		
	10.45	60 min		8.5		7		7.2		
	11.45	120 min	17	8.5	1	7.5		7.7		?
	1.45	240 min	18.5	7	1	6		8.2		
	5.45	480 min	20.5	6	0.5	5.5		8.7		
	9.05	1440 min	15.5	6	1.5	4.5		9.5		restarted
HT08-G01-4a	9.52	30 sec	15.5	14.5	1.5	13		3.8	050386	
	9.52	45 sec		14.5		13		4.1		
	9.53	1 min		14		12.5		4.3		
	9.54	2 min		14		12.5		4.8		
	9.57	5 min		14		12.5		5.5		
	10.07	15 min	16	13	1.5	11.5		6.3		
	10.22	30 min		12		10.5		6.7		
	10.52	60 min		10		8.5		7.2		
	11.52	120 min	17	8	1	7		7.7		
	1.52	240 min	18.5	6.5	1	5.5		8.2		
	5.52	480 min	20.5	5	0.5	4.5		8.7		
	9.07	1440 min	15.5	6	1.5	4.5		9.5		restarted
HT08-G02-4	9.31	30 sec	16	12.5	1.5	11		3.8	050386	
	9.31	45 sec		12.5		11		4.1		
	9.32	1 min		12.5		11		4.3		
	9.33	2 min		12		10.5		4.8		
	9.36	5 min		11		9.5		5.5		
	9.46	15 min		9.5		8		6.3		
	10.01	30 min		8.5		7		6.7		
	10.31	60 min	16.5	7.5	1	6.5		7.2		
	11.31	120 min	17	7	1	6		7.7		
	1.31	240 min	18.5	6.5	1	5.5		8.2		

Sample	Time	Elapsed time	Temp ©	Reading	Corr Factor	Corr reading	Cum % coarser	Phi class	Hydro no.	Comments
HT08-G02-4 con't	5.31	480 min	19.5	6	1	5		8.7		
	9.31	1440 min	16	6	1.5	4.5		9.5		
HT08-G02-3	9.38	30 sec	16	13	1.5	11.5		3.8	050386	
	9.38	45 sec		13		11.5		4.1		
	9.39	1 min		13		11.5		4.3		
	9.40	2 min		12.5		11		4.8		
	9.43	5 min		12		10.5		5.5		
	9.53	15 min		10		8.5		6.3		
	10.08	30 min		8.5		7		6.7		
	10.38	60 min	16.5	8	1	7		7.2		
	11.38	120 min	17	7	1	6		7.7		
	1.38	240 min	18.5	7	1	6		8.2		
	5.38	480 min	19.5	6	1	5		8.7		
	9.38	1440 min	16	6	1.5	4.5		9.5		
HT08-T01-4	9.11	30 sec	15.5	7.5	1.5	6		3.8	050386	
	9.11	45 sec		7.5		6		4.1		
	9.12	1 min		7.5		6		4.3		
	9.13	2 min		7		5.5		4.8		
	9.16	5 min		6		4.5		5.5		
	9.26	15 min	16	5.5	1.5	4		6.3		
	9.41	30 min		4.5		3		6.7		
	10.11	60 min		4.5		3		7.2		
	11.11	120 min	17.5	4	0	4		7.7		?
	1.11	240 min	18.5	4	0	4		8.2		
	5.11	480 min	20	4	1	3		8.7		
	9.11	1440 min	15.5	5	1.5	3.5		9.5		
HT08-T01-5	9.18	30 sec	15.5	8	1.5	6.5		3.8	050386	
	9.18	45 sec		8		6.5		4.1		

Sample	Time	Elapsed time	Temp ©	Reading	Corr Factor	Corr reading	Cum % coarser	Phi class	Hydro no.	Comments
HT08-T01-5 con't	9.19	1 min		7.5		6		4.3		
	9.20	2 min	16	7	1.5	5.5		4.8		
	9.23	5 min		6.5		5		5.5		
	9.33	15 min		5.5		4		6.3		
	9.48	30 min		5		3.5		6.7		
	10.18	60 min		4		2.5		7.2		
	11.18	120 min	17.5	4	0	4		7.7		?
	1.18	240 min	18.5	4	0	4		8.2		
	5.18	480 min	20	3.5	1	2.5		8.7		
	9.18	1440 min	15.5	5	1.5	3.5		9.5		?
HT08-T01-6	9.25	30 sec	16	8	1.5	6.5		3.8	050386	
	9.25	45 sec		8		6.5		4.1		
	9.26	1 min		7.5		6		4.3		
	9.27	2 min		7.5		6		4.8		
	9.30	5 min		6		4.5		5.5		
	9.40	15 min		5		3.5		6.3		
	9.55	30 min		5		3.5		6.7		
	10.25	60 min		4.5		3		7.2		
	11.25	120 min	17.5	3.5	0	3.5		7.7		
	1.25	240 min	18.5	3.5	0	3.5		8.2		
	5.25	480 min	20	3	1	2		8.7		
	9.25	1440 min	15.5	4.5	1.5	3		9.5		?
HT08-T01-2	9.31	30 sec	15.5	5.5	1.5	4		3.8	050386	
	9.31	45 sec		5.5		4		4.1		
	9.32	1 min		5.5		4		4.3		
	9.33	2 min		5		3.5		4.8		
	9.36	5 min		5		3.5		5.5		
	9.46	15 min		4.5		3		6.3		
	10.01	30 min		4.5		3		6.7		

Sample	Time	Elapsed time	Temp ©	Reading	Corr Factor	Corr reading	Cum % coarser	Phi class	Hydro no.	Comments
HT08-T01-2 con't	10.31	60 min	16.5	4	1	3		7.2		
	11.31	120 min	17.5	4	1.5	2.5		7.7		
	1.31	240 min	18.5	3	0.5	2.5		8.2		
	5.31	480 min	20	3	0.5	2.5		8.7		
	9.31	1440 min	15	4	0.5	3.5		9.5		?
HT08-G01-2a	9.38	30 sec	15.5	16	1.5	14.5		3.8	050386	
	9.38	45 sec		16		14.5		4.1		
	9.39	1 min		15.5		14		4.3		
	9.40	2 min		14.5		14		4.8		
	9.43	5 min		12		10.5		5.5		
	9.53	15 min		11		9.5		6.3		
	10.08	30 min	16.5	10	1	9		6.7		
	10.38	60 min		9		8		7.2		
	11.38	120 min	17.5	8	1.5	6.5		7.7		
	1.38	240 min	18.5	7	0.5	6.5		8.2		
	5.38	480 min	20	6	0.5	5.5		8.7		
	9.38	1440 min	15	6	0.5	5.5		9.5		
HT08-G01-3a	9.48	30 sec	15.5	27	1.5	25.5		3.8	050386	
	9.48	45 sec		27		25.5		4.1		
	9.49	1 min		26.5		25		4.3		
	9.50	2 min		25.5		24		4.8		
	9.53	5 min		23		21.5		5.5		
	10.03	15 min		21		19.5		6.3		
	10.18	30 min	16.5	19.5	1	18.5		6.7		
	10.48	60 min		17		16		7.2		
	11.48	120 min	17.5	15	1.5	13.5		7.7		
	1.48	240 min	18.5	13	0.5	12.5		8.2		
	5.48	480 min	20	12	0.5	11.5		8.7		
	9.48	1440 min	15	11	0.5	10.5		9.5		

E.1.2 Sand fraction weights

Sample	Diam (mm)	Sieve no	Phi class	Weight (g)	Cumul % Coarser	Comments
HT08-T01-7	4mm	5	-2	0	0	
	2mm	10	-1	0.01	0	twig
	1mm	18	0	0	0	
	0.5	35	1	0.007	0	
	0.25	60	2	0.394	1	
	0.125	120	3	5.523	21	
	0.063	230	4	9.778	56	
		PF		5.129	74	
HT08-T01-11	4mm	5	-2	0	0	
	2mm	10	-1	0	0	
	1mm	18	0	0.001	0	OM
	0.5	35	1	0.046	0	
	0.25	60	2	1.191	4	
	0.125	120	3	6.286	26	
	0.063	230	4	10.367	62	
		PF		5.171	80	
HT08-G02-9	4mm	5	-2	0	0	
	2mm	10	-1	0.075	0	
	1mm	18	0	0.069	0	
	0.5	35	1	0.135	0	
	0.25	60	2	1.387	5	
	0.125	120	3	5.236	23	
	0.063	230	4	5.737	42	
		PF		3.832	55	
HT08-G01-4a	4mm	5	-2	0.079	0	
	2mm	10	-1	0.195	1	
	1mm	18	0	0.113	1	
	0.5	35	1	0.68	3	
	0.25	60	2	0.73	5	
	0.125	120	3	1.693	10	
	0.063	230	4	2.483	18	
		PF		5.265	35	
HT08-T01-4	4mm	5	-2	0	0	
	2mm	10	-1	0	0	
	1mm	18	0	0	0	
	0.5	35	1	0.87	3	
	0.25	60	2	0.422	5	
	0.125	120	3	4.747	22	
	0.063	230	4	7.233	48	
		PF		7.28	74	

Sample	Diam (mm)	Sieve no	Phi class	Weight (g)	Cumul % Coarser	Comments
HT08-T01-2	4mm	5	-2	0	0	
	2mm	10	-1	0.266	1	
	1mm	18	0	0.509	3	
	0.5	35	1	1.024	7	
	0.25	60	2	4.301	22	
	0.125	120	3	12.147	64	
	0.063	230	4	4.696	81	
		PF		1.41	86	
HT08-G02-4	4mm	5	-2	0	0	
	2mm	10	-1	0.019	0	
	1mm	18	0	0.031	0	
	0.5	35	1	0.055	0	
	0.25	60	2	1.656	5	
	0.125	120	3	7.015	28	
	0.063	230	4	6.542	49	
		PF		3.566	60	
HT08-G02-3	4mm	5	-2	0	0	
	2mm	10	-1	0	0	
	1mm	18	0	0	0	
	0.5	35	1	0	0	
	0.25	60	2	0.38	1	
	0.125	120	3	3.896	14	
	0.063	230	4	6.907	38	
		PF		6.275	59	
HT08-T01-5	4mm	5	-2	0	0	
	2mm	10	-1	0	0	
	1mm	18	0	0	0	
	0.5	35	1	0	0	
	0.25	60	2	2.745	9	
	0.125	120	3	15.184	57	
	0.063	230	4	5.304	74	
		PF		2.112	81	
HT08-G01-2a	4mm	5	-2	0	0	
	2mm	10	-1	0.015	0	
	1mm	18	0	0.039	0	
	0.5	35	1	0.044	0	
	0.25	60	2	0.835	3	
	0.125	120	3	7.072	26	
	0.063	230	4	5.006	42	
		PF		2.206	49	

Sample	Diam (mm)	Sieve no	Phi class	Weight (g)	Cumul % Coarser	Comments
HT08-T01-6	4mm	5	-2	0	0	
	2mm	10	-1	0	0	
	1mm	18	0	0.003	0	
	0.5	35	1	0.024	0	
	0.25	60	2	0.689	2	
	0.125	120	3	7.833	30	
	0.063	230	4	8.54	61	
		PF		4.922	79	
HT08-G01-3a	4mm	5	-2	0	0	mostly clays
	2mm	10	-1	0.019	0	
	1mm	18	0	0.054	0	
	0.5	35	1	0.117	0	
	0.25	60	2	0.246	1	
	0.125	120	3	1.078	5	
	0.063	230	4	1.416	10	
		PF		0.518	12	

E.2 Magnetic susceptibility readings

Sample No	Weight (g)	Low freq pre-fire	High freq pre-fire	Low freq post-fire	high freq post-fire
T01-2	10	309.5	308.3	263.1	263.3
T01-4	10	174.6	173.5	144.5	143.5
T01-5	10	202.3	201	169.8	169
T01-6	10	162	160.6	132.7	132.1
T01-7	10	181.8	179.6	150.4	149.8
T01-11	10	234.3	233.9	201.7	201.2
G01-2a	10	166.9	162	152.7	150.5
G01-3a	10	143.6	138.7	145.9	140.1
G01-4a	10	135.6	130.8	132	127.9
G02-3	10	198.2	196.9	168.5	169.1
G02-4	10	158.2	156.9	143.7	141.9
G02-9	10	180.4	150	164.3	163.7

Sample No	Weight (g)	Low freq pre-fire	High freq pre-fire	Low freq post-fire	high freq post-fire
T01-2	10	309.5	308.3	263.1	263.3
G01-2a	10	166.9	162	152.7	150.5
G01-3a	10	143.6	138.7	145.9	140.1
G01-4a	10	135.6	130.8	132	127.9
T01-4	10	174.6	173.5	144.5	143.5
T01-5	10	202.3	201	169.8	169
T01-6	10	162	160.6	132.7	132.1
G02-3	10	198.2	196.9	168.5	169.1
G02-4	10	158.2	156.9	143.7	141.9
T01-7	10	181.8	179.6	150.4	149.8
T01-11	10	234.3	233.9	201.7	201.2
G02-9	10	180.4	150	164.3	163.7

E.3 Loss on ignition and phosphate analysis results

Sample No	Pre-fire weight (g)	Post-fire weight (g)	Percentage loss	phosphate reading
T01-2	24.037	23.897	1	1
T01-4	19.77	19.5	1	3
T01-5	20.795	20.553	1	2
T01-6	19.5	19.243	1	1
T01-7	24.475	24.24	1	1
T01-11	20.88	20.697	1	1
G01-2a	19.625	19.331	2	2
G01-3a	27.722	27.222	2	3
G01-4a	19.47	19.081	2	3
G02-3	27.379	26.982	2	1
G02-4	27.037	26.743	1	2
G02-9	27.431	27.106	1	1

Appendix F

Phytolith count sheets

These sheets are a development of count sheets initially developed by Prof Rosen at the Institute of Archaeology. The International Code for Phytolith Nomenclature 1.0 was followed where possible; in some cases, traditional terms (such as rondel) were kept.

Phytolith count sheet

Site		**Top right**
Sample No.		**Fields single**
		Fields multi
MONOCOTS		
Single cells		
Grass	Psilate long cell	
	Sinuate long cell	
Inflor.	Dentritic long cell	
	Trapezoid sinuate/crenate	
	Papillae	
	?Emmer papillae (stubble)	
	Keystone bulliform	
Grass leaf	Bilobe Chloridoid (C4)	
(tall grass)	Bilobe Panicoid (Most C4)	
reed, phrag	Bilobe Aruninoid (Most C3)	
	Bilobe indet	
	Saddle Chloridoid	
	Saddle Aruninoid	
	Saddle indet	
	Polylobate	
Panicoid	Quadralobe	
(pooid)	Rondel	
	Flat tower	
	Horned tower	
stem	Elliptical psilate	
stem	rectangular psilate (small)	
Indet	Grass SC indet	
Mono inflor	Echinate long cell	
	Crenate LC	
	Psilate long cell rod	
	Echinate long cell rod	
	Cylindric psilate long cell	
	Psilate assymetrical LC	
	Echinate assymetrical LC	
	Psilate LC w/projections on 1 side	
	Prickle hairs	
leaf	Tricomes	
	Hairs	
leaf	Bulliforms	
	?Bulliform (Echinate semi-sphere)	
Mono leaf	Stomata	
Sedge	Tetracytic stomata (?Scirpus)	
Sedge	Sedge cones	
Palm	Globular echinate cf date palm	
Palm (Nile)	Globular spinulose cf Doum palm	
	Trapezoid	
	Indet monocot SC	

Aquatic/?scirpus (root)	Silicified stellate parenchyma

No. fields counted   Tot sample wt   Tot phyt wt   Tot mount wt

Phytolith count sheet

Site	
Sample No.	

MONOCOTS	
Multicells	
leaf/stem	
grass	Silica skeleton psilate LC
grass	Silica skeleton sinuate LC
monocot	Silica skeleton echinate LC
monocot	Indet monocot leaf/stem
monocot	Silica skelton LC and stomata
grass	leaf/stem with grass stomata
pooid	leaf/stem with rondels
grass	leaf/stem with bilobes indet
C4 grass	leaf/stem with chloridoid bilobes
tall grass	leaf/stem with panicoid bilobes
reed/phrags	leaf/stem with arunidoid bilobes
	Phragmite leaf
	phragmite stem
	leaf/stem with saddles indet
C4 grass	leaf/stem with choridoid saddles
reed/phrags	leaf/stem with arunidoid saddles
not pooid	leaf/stem with quadralobes
?Sedge	leaf/stem with bulliforms
	leaf/stem with crenates
	square cell leaf/stem
	multiple bulliforms
	Stem with hair
grass/sedge	Assymetrical LCs
Sedge	Cylindrical (rods) and LCs
Sedge	Sedge cones
Sedge leaves	Visible mesophyll
Cereal/grass	
wheat/barley	Indet husk
domesticate	Wheat husk indet
domesticate	Emmer wheat
domesticate	Durum wheat
	Einkorn wheat
	Bread wheat
?dom/wild	Barley husk
domesticate	Cereal straw
cereal	Awn
cereal	Papillae aggragation (distal)
Wild/agri weed	Setaria
Wild	Aegilops (goat grass)
Wild	Bromus
Wild	Avena (oat grass)
Wild	Lolium (rye grass)
Sedge	Scirpus type (tetracytic stomata)
Wild	Wild grass husk
	Stem (indet grass)
Wild	panicoid bilobes
	Indet MC

No. fields counted Tot sample wt Tot phyt wt Tot mount wt

Phytolith count sheet

Site	
Sample No.	

DICOTS	
Single cells	
bark/wood	Globular psilate
?bark/wood	Globular multifaceted
?bark/wood	Globular verrucate
	Dicot elongate (oblong)
arb/herb leaf	Tracheid
wood	Blocks (parallelpiped)
	Platey
wood	Sheet - clear (platelet)
wood	Sheet - scrobiculate
wood	Sheet - spotted
?Vitex agnus castu	Sheet - striated
leaf/branch	Tricomes (cf Metcalfe)
Asteraceae floral	Opaque platelets (Bozarth)
dicots/conifers	solid opaque platelets
arb/herb leaf	Single polyhedral (Bozarth)
fruit/seeds	Decorated polyhedral (4-8 sides)
arb/herb leaf	Single jigsaw
	Verrucate
	Stipa type rondel
	Scalloped (round)
	Scalloped (see Bozarth)
needles	Pinaceae tracheids
pinus sp leaf	Irregular echinate LC
needles	Conifer blocky polyhedral (>8 side)
?fruit seeds	Sclereid
	Astrosclereid
?cf Chenopods	large sphere (holes)
	Stellate
	Indet dicot SC
Multicells	Multi LCs
Leaf/stem	Multiple jigsaws
	polyhedral (Bozarth)
Friut/seeds	decorated polyhedral (4-8 sides)
usually leaf	Hairbase
	cf oak
bark	Silica aggregates
	Palisade/mesophyll (Bozarth)
	Favose (large)
	Favose (small)
	Honeycomb favose
	Indet dicot multicell
Grape epidermis	?Vitis sp
OTHER	
Polypodiaceae	Very long sinuate LC (fern)
Equisetum	Stomata with uneven dentritic LC
	Sponge spicules
	Diatoms

No. fields counted Tot sample wt Tot phyt wt Tot mount wt

Appendix G

Hirbemerdon Tepe phytolith analysis: raw data I

G.1 Offsite samples

Site: HT terrace samples									
Sample	**T01-7**	**T01-7a**	**G02-4**	**G02-3**	**T01-6**	**T01-5**	**T01-4**	**G01-4c**	**G01-4a**
MONOCOTS									
SINGLE CELLS									
Psilate long cell	107	1527	19	645	29	41	430	153119	70265
Sinuate long cell	12	58	3	95	4	10	25	8145	5489
Dentritic long cell	6	58	0	60	26	10	59	70044	18664
Trapezoid sinuate/crenate	24	202	11	52	7	20	25	19547	6587
Papillae	0	231	0	0	4	0	25	0	3294
?Emmer papillae (stubble)	0	0	0	0	0	0	0	0	0
Keystone bulliform	30	432	8	120	4	41	169	4887	3294
Bilobe Chloridoid (C4)	0	0	0	0	0	0	0	0	0
Bilobe Panicoid (Most C4)	0	0	0	0	0	0	25	0	0
Bilobe Aruninoid (Most C3)	0	0	0	0	0	0	8	0	0
Bilobe indet	0	29	0	26	0	15	25	1629	1098
Saddle Chloridoid	0	0	0	0	0	0	0	0	0
Saddle Aruninoid	0	0	0	0	0	0	0	0	0
Saddle indet	0	0	0	0	0	36	0	4887	3294
Polylobate	6	144	3	43	7	10	59	0	3294
Quadralobe	0	0	0	0	0	0	0	0	0
Rondel	36	288	16	378	7	0	68	78188	86733
Flat tower	12	58	0	0	0	0	17	0	4392
Horned tower	0	29	3	9	0	0	25	0	0
Elliptical psilate	0	202	0	0	0	5	76	4887	1098
rectangular psilate (small)	6	231	5	69	18	82	76	14660	9881
Grass SC indet	0	0	0	0	0	0	0	0	0
Echinate long cell	6	259	3	86	18	20	51	30949	16468
Crenate LC	6	0	0	0	0	0	0	0	3294
Psilate long cell rod	0	375	3	52	15	97	93	30949	12077
Echinate long cell rod	0	0	0	52	7	20	8	4887	0
Cylindric psilate long cell	0	0	0	0	0	0	0	0	0
Psilate assymetrical LC	36	231	11	249	22	56	160	50497	29643
Echinate assymetrical LC	6	29	3	0	0	0	8	3258	3294

Site: HT terrace samples									
Sample	T01-7	T01-7a	G02-4	G02-3	T01-6	T01-5	T01-4	G01-4c	G01-4a
MONOCOTS, con't									
SINGLE CELLS, con't									
Psilate LC w/projections on 1 side	18	115	0	34	4	15	42	6516	0
Prickle hairs	30	231	8	52	0	97	152	1629	6587
Tricomes	42	346	8	163	15	0	194	11402	9881
Hairs	6	86	0	17	0	0	34	1629	3294
Bulliforms	48	980	32	387	7	46	152	8145	17566
?Bulliforms (echinate semi-sphere)	0	115	0	0	0	0	8	0	1098
Stomata	0	0	0	0	0	5	0	0	0
Tetracytic stomata (?Scirpus)	0	0	0	0	0	0	0	0	0
Sedge cones	42	2824	35	266	77	368	532	57012	27447
Globular echinate cf date palm	0	0	0	0	0	0	0	0	0
Globular spinulose cf Doum palm	0	0	0	0	0	0	0	0	0
Globular verrucate (large)	0	0	0	0	0	0	0	0	0
Trapezoid	6	86	0	249	15	92	160	21176	21958
Indet monocot SC	54	432	24	120	44	0	42	14660	13175
TOTAL MONOCOT SINGLE CELLS	535	9595	191	3223	332	1090	2752	602700.71	383162.3
MULTICELLS									
Silica skeleton psilate LC	0	134	8	14	4	26	75	4003	4035
Silica skeleton sinuate LC	0	4	0	2	0	0	5	500	526
Silica skeleton echinate LC	0	12	0	8	4	0	5	667	351
Indet monocot leaf/stem	0	73	3	16	15	41	21	1001	1754
Silica skelton LC and stomata	0	0	0	0	0	0	0	0	0
leaf/stem with grass stomata	0	0	0	0	0	0	0	0	0
leaf/stem with rondels	0	0	0	2	0	0	5	0	526
leaf/stem with bilobes indet	0	0	0	0	0	0	0	0	0
leaf/stem with chloridoid bilobes	0	0	0	0	0	0	0	0	0
leaf/stem with panicoid bilobes	0	0	0	0	0	0	0	0	0
leaf/stem with arunidoid bilobes	0	0	0	0	0	0	0	0	0

Site: HT terrace samples									
Sample	T01-7	T01-7a	G02-4	G02-3	T01-6	T01-5	T01-4	G01-4c	G01-4a
MULTICELLS, con't									
Phragmite leaf	0	0	0	0	0	0	11	0	0
phragmite stem	0	0	0	0	0	0	0	0	0
leaf/stem with saddles indet	0	0	0	0	0	0	0	0	0
leaf/stem with choridoid saddles	0	0	0	0	0	0	0	0	0
leaf/stem with arunidoid saddles	0	0	0	0	0	0	0	0	0
leaf/stem with quadralobes	0	0	0	0	0	0	0	0	0
leaf/stem with bulliforms	0	0	0	10	0	0	5	667	0
leaf/stem with crenates	0	0	0	0	0	0	0	0	0
square cell leaf/stem	0	0	0	0	0	5	0	500	175
multiple bulliforms	0	0	0	8	0	0	11	667	175
Stem with hair	0	16	0	0	0	0	11	0	0
Assymetrical LCs	6	41	5	16	4	15	11	1501	351
Cylindrical (rods) and LCs	6	33	3	14	7	10	21	1001	2807
Sedge cones	0	24	0	0	0	36	86	334	0
Visible mesophyll	0	0	0	0	0	0	0	334	175
Indet husk	0	0	0	0	0	0	0	2168	2456
Wheat husk indet	0	0	0	0	0	0	0	0	175
Emmer wheat	0	0	0	0	18	0	0	0	0
Durum wheat	0	0	0	0	0	0	0	0	0
Einkorn wheat	0	0	0	0	0	0	0	0	0
Bread wheat	0	0	0	0	0	0	0	0	0
Barley husk	0	0	0	0	0	0	0	0	0
Cereal straw	0	0	0	0	0	5	0	0	526
Awn	0	4	0	0	0	0	0	500	526
Papillae aggragation (distal)	0	0	0	0	0	0	0	0	175
Setaria	0	0	0	0	0	0	0	167	0
Aegilops (goat grass)	0	0	0	2	0	0	0	0	0
Bromus	0	0	0	2	0	0	0	0	351

Site: HT terrace samples									
Sample	T01-7	T01-7a	G02-4	G02-3	T01-6	T01-5	T01-4	G01-4c	G01-4a
MULTICELLS, con't									
Wild grass husk	0	8	0	0	0	0	21	500	526
Stem (indet grass)	0	0	0	4	0	0	0	0	175
panicoid bilobes	0	0	0	0	0	0	0	0	0
Indet MC	0	8	0	10	26	41	11	167	1053
TOTAL MONOCOT MULICELLS	12	359	19	106	77	179	299	14676.966	16842
TOTAL MONOCOTS	547	9953	210	3329.02	409	1269	3051	617377.67	400004.1
DICOTS									
SINGLE CELLS									
Globular psilate	0	29	0	17	0	0	8	0	2196
Globular multifaceted	0	0	0	0	0	0	8	0	0
Globular verrucate (small)	18	375	3	9	0	15	84	0	1098
Dicot elongate (oblong)	0	58	0	17	0	0	59	0	0
Tracheid	6	86	0	0	11	36	17	1629	1098
Blocks	0	58	0	9	0	5	17	0	1098
Platey	0	0	0	0	0	0	0	0	0
Sheet - clear (platelet)	12	547	8	26	0	0	51	1629	0
Sheet - scrobiculate	0	288	0	0	0	0	0	3258	1098
Sheet - spotted	6	0	0	26	0	0	34	0	0
Sheet - striated	0	0	0	0	0	0	0	0	0
Tricomes (cf Metcalfe)	0	0	0	0	0	0	8	0	0
Opaque platelets (Bozarth)	0	0	0	0	0	0	0	0	0
solid opaque platelets	0	29	0	0	26	113	8	0	0
Single polyhedral (Bozarth)	54	634	19	206	7	61	186	53754	39524
Decorated polyhedral (4-8 sides)	12	0	0	34	0	0	42	4887	2196
Single jigsaw	6	86	5	17	0	5	101	17918	15370
Verrucate	0	0	0	43	0	10	0	0	0
Stipa type rondel	0	0	0	0	0	0	0	0	0
Scalloped (round)	0	0	0	0	0	0	0	0	0

Site: HT terrace samples									
Sample	T01-7	T01-7a	G02-4	G02-3	T01-6	T01-5	T01-4	G01-4c	G01-4a
SINGLE CELLS									
Pinaceae tracheids	0	0	0	0	0	0	0	0	0
Irregular echinate LC	0	0	0	0	0	0	17	0	0
Conifer blocky polyhedral (>8 side)	0	0	0	0	0	0	0	0	0
Sclereid	30	86	0	43	0	0	0	0	3294
Astrosclereid	0	0	0	0	0	0	0	0	0
large sphere (holes)	0	0	0	9	0	5	8	0	0
Stellate	0	115	0	0	0	0	17	0	0
Indet dicot SC	59	2190	5	77	44	251	633	4887	4392
TOTAL DICOT SINGLE CELLS	202	4581	40	533	88	502	1299	87962	71363
MULTICELLS									
Multi LCs	0	0	0	0	4	5	0	0	0
Multiple jigsaws	0	0	0	0	0	0	5	0	175
polyhedral (Bozarth)	0	0	0	6	0	5	0	167	0
decorated polyhedral (4-8 sides)	0	0	0	0	0	0	0	0	0
Hairbase	0	0	0	0	0	0	0	0	0
cf oak	0	0	0	0	0	0	5	0	351
Silica aggregates	0	8	8	2	0	0	70	334	175
Palisade/mesophyll (Bozarth)	0	4	0	0	0	0	0	0	0
Favose (large)	0	0	0	2	0	0	0	0	0
Favose (small)	0	0	0	2	0	0	0	0	0
Honeycomb favose	0	0	0	2	0	0	0	0	0
Indet dicot multicell	0	24	0	2	0	10	43	667	175
?Vitis sp	0	0	0	0	0	0	11	0	0
TOTAL DICOT MULTICELLS	0	37	8	16	4	20	134	1167	877
TOTAL DICOTS	202	4618	48	549	92	522	1433	89129	72240
TOTAL SINGLE CELLS	737	14176	231	3756	420	1591	4051	690662.67	454525.3
TOTAL MULTICELLS	12	395	27	122	81	199	433	15844	17719

Site: HT terrace samples									
Sample	T01-7	T01-7a	G02-4	G02-3	T01-6	T01-5	T01-4	G01-4c	G01-4a
OTHER									
Very long sinuate LC (fern)	0	29	0	0	0	0	0	0	0
Stomata with uneven dentritic LC	0	0	0	0	0	0	0	0	0
Sponge spicules	0	29	0	0	0	0	25	0	1098
Diatoms	0	115	0	0	0	0	8	0	4392
TOTAL OTHER	**0**	173	0	0	0	0	34	0	5489
Sample no and date	**T01-7: ?EBA**	**T01-7a: ?EBA**	**G02-4: EBA**	**G02-3: EBA**	**T01-6: EBA**	**T01-5: EBA-MBA**	**T01-4: - MBA**	**G01-4c: MBA**	**G01-4a: MBA**
TOTAL PHYTOLITHS	749	14571	258	3878	501	1791	4484	706507.12	472244.3
TOTAL SILICA CONTENT	**0.5**	0.5	0.3	0.6	0.7	0.9	0.7	5.2	4
TOTAL SEDGES	6	57	3	14	7	46	107	1668	2982
TOTAL REEDS/PHRAGMITES MC	**0**	0	0	0	0	0	11	0	0
TOTAL WETLAND PLANTS MC	6	57	3	14	7	46	118	1668	2982
TOTAL WILD GRASS MC	**0**	139	8	18	4	26	86	4503	5088
TOTAL CEREALS MC	**0**	4	0	0	18	5	0	2669	3684
TOTAL GRASSES	**0**	143	8	18	22	31	86	7172	8772
TOTAL ?FRUIT	12	0	0	34	0	0	53	4887	2196
TOTAL DICOT LEAF	65	807	24	229	18	107	337	73468	56168
TOTAL BARK/WOOD	**18**	959	16	79	26	118	188	5220	4567
ADJUSTED DICOT ABUNDANCE (SC X15)	**3210**	63,960	600	8250	1320	7530	18735	1319430	1053975
Total rondel SC	48	375	19	387	7	0	110	78188	91125
Total bilobes	0	29	0	26	0	15	59	1629	1098
Total saddles	0	0	0	0	0	36	0	4887	3294

G.2 Onsite samples

Site: HT onsite samples								
Sample	SC19-1	SC8-1	SC99-1	SC147-1	SC147-2	SC518-2	SC518-3	SC149-2
MONOCOTS								
SINGLE CELLS								
Psilate long cell	43644	9294	441647	92356	111747	21916	34064	56760
Sinuate long cell	3594	6084	0	9779	12081	9897	12462	2735
Dentritic long cell	7188	11660	173982	18471	18121	62212	63143	12993
Trapezoid sinuate/crenate	7188	2197	40150	6519	22651	4242	0	10942
Papillae	1027	676	120449	0	0	12725	13293	684
?Emmer papillae (stubble)	0	0	0	1087	0	0	0	0
Keystone bulliform	4108	3718	13383	1087	1510	707	9970	5471
Bilobe Chloridoid (C4)	0	0	0	0	0	0	0	0
Bilobe Panicoid (Most C4)	0	0	0	0	0	0	0	0
Bilobe Aruninoid (Most C3)	0	0	0	0	0	0	0	0
Bilobe indet	0	1521	0	0	1510	2828	4154	0
Saddle Chloridoid	0	0	0	0	0	0	0	0
Saddle Aruninoid	0	0	0	0	0	0	0	0
Saddle indet	513	2366	267665	3260	4530	5656	4154	1368
Polylobate	513	0	40150	2173	6040	2828	1662	684
Quadralobe	0	169	80300	0	1510	707	1662	0
Rondel	35942	5746	1298176	76058	113257	23330	24925	45135
Flat tower	0	1183	13383	4346	4530	6363	3323	1368
Horned tower	0	0	0	1087	1510	3535	831	684
Elliptical psilate	0	0	13383	7606	0	0	17447	1368
rectangular psilate (small)	5648	1859	160599	14125	10571	1414	13293	10942
Grass SC indet	0	0	0	0	0	0	0	0
Echinate long cell	4108	5577	133833	17385	13591	16260	17447	2735
Crenate LC	0	0	0	0	0	0	0	684

Site: HT onsite samples								
Sample	SC149-4	S01-8	SC160-6	SC517-1	SC551-1	SC569-1	SC148-7	SC607-1
MONOCOTS								
SINGLE CELLS								
Psilate long cell	166890	156348	244858	142891	48250	44251	57966	16142
Sinuate long cell	26822	19768	15969	19310	3632	5957	5434	3228
Dentritic long cell	74505	17971	58553	17379	5707	19572	19926	22599
Trapezoid sinuate/crenate	23841	14377	15969	9655	3632	1702	5434	5811
Papillae	0	0	18631	5793	1038	2553	0	9040
?Emmer papillae (stubble)	0	0	0	0	0	0	0	0
Keystone bulliform	5960	14377	2662	11586	1038	2127	1811	12268
Bilobe Chloridoid (C4)	0	0	0	0	0	0	0	0
Bilobe Panicoid (Most C4)	0	0	0	0	0	0	0	0
Bilobe Aruninoid (Most C3)	0	0	0	0	0	0	0	0
Bilobe indet	2980	1797	5323	0	0	425	0	5166
Saddle Chloridoid	0	0	0	0	0	851	0	0
Saddle Aruninoid	0	0	0	3862	0	0	0	0
Saddle indet	2980	8986	2662	3862	0	0	906	7103
Polylobate	2980	1797	0	9655	519	851	906	5166
Quadralobe	0	0	7985	0	0	0	906	1937
Rondel	253315	181507	202274	117789	33204	16169	95101	36159
Flat tower	8941	7188	7985	23172	519	5531	11774	2583
Horned tower	2980	8986	0	19310	519	1276	5434	0
Elliptical psilate	2980	0	0	5793	519	1276	906	0
rectangular psilate (small)	44703	5391	13308	9655	8301	2127	5434	8394
Grass SC indet	0	0	0	0	0	0	0	0
Echinate long cell	47683	39536	79845	34757	8301	8084	19926	7748
Crenate LC	0	0	5323	3862	519	0	0	0

Site: HT onsite samples								
Sample	SC550-1	SC624-1	SC624-2	SC624-3	SC625-1	SC625-2	SC626-2	SC606-1
MONOCOTS								
SINGLE CELLS								
Psilate long cell	29321	27833	400377	37393	3436	4397	20754	65832
Sinuate long cell	16385	3676	28598	3252	308	2103	9224	4448
Dentritic long cell	7761	14704	114393	18697	837	7073	23060	5338
Trapezoid sinuate/crenate	7761	7877	85795	4877	352	3059	9993	11565
Papillae	3449	4201	21449	0	573	1912	4612	3558
?Emmer papillae (stubble)	0	0	0	0	0	0	0	0
Keystone bulliform	31045	6827	21449	4877	176	3632	16911	890
Bilobe Chloridoid (C4)	0	0	0	0	0	0	0	0
Bilobe Panicoid (Most C4)	0	0	0	0	0	0	0	0
Bilobe Aruninoid (Most C3)	0	0	0	0	0	0	0	0
Bilobe indet	12936	3151	21449	0	44	2103	7687	0
Saddle Chloridoid	0	0	0	0	88	0	0	0
Saddle Aruninoid	0	0	0	0	0	0	0	0
Saddle indet	8624	6827	14299	4877	0	2294	21523	890
Polylobate	6037	3676	50047	5690	132	956	3075	1779
Quadralobe	0	525	0	0	44	191	0	0
Rondel	13798	21531	636313	56090	1409	5735	38433	76507
Flat tower	5174	6302	21449	2439	484	1147	6149	890
Horned tower	0	0	0	813	220	0	1537	1779
Elliptical psilate	7761	0	7150	3252	88	382	0	1779
rectangular psilate (small)	11211	5252	64346	15445	969	1912	9224	11565
Grass SC indet	0	0	0	0	0	0	0	0
Echinate long cell	13798	6827	64346	18697	705	1912	9224	9786
Crenate LC	0	0	0	0	0	0	0	0

Site: HT onsite samples						
Sample	**SC606-2**	**SC615-1**	**S01-7a**	**S01-7b**	**S01-6**	**S01-6a**
MONOCOTS						
SINGLE CELLS						
Psilate long cell	22079	28768	19434	14088	115496	65831
Sinuate long cell	589	10599	1943	2348	12229	19571
Dentritic long cell	5593	29525	11661	27394	23099	129882
Trapezoid sinuate/crenate	3238	8328	5830	6262	8153	5338
Papillae	1178	5299	0	4696	0	7117
?Emmer papillae (stubble)	0	0	0	0	1359	0
Keystone bulliform	1766	9085	2915	2348	1359	3558
Bilobe Chloridoid (C4)	0	0	0	0	0	0
Bilobe Panicoid (Most C4)	0	0	0	0	0	0
Bilobe Aruninoid (Most C3)	0	0	0	0	0	0
Bilobe indet	0	5299	972	8610	0	3558
Saddle Chloridoid	0	0	0	0	0	0
Saddle Aruninoid	0	0	0	0	0	0
Saddle indet	0	9085	8260	38352	4076	19571
Polylobate	294	3028	972	1565	2718	7117
Quadralobe	0	0	0	6262	0	3558
Rondel	23845	27254	41298	51657	95115	119207
Flat tower	294	2271	2915	1565	5435	21350
Horned tower	294	0	2915	783	1359	0
Elliptical psilate	294	0	0	0	9511	0
rectangular psilate (small)	3827	4542	2915	3131	17664	7117
Grass SC indet	0	0	0	0	0	0
Echinate long cell	2649	18926	5830	25046	21740	76506
Crenate LC	0	0	0	0	0	0

Site: HT onsite samples								
Sample	SC19-1	SC8-1	SC99-1	SC147-1	SC147-2	SC518-2	SC518-3	SC149-2
SINGLE CELLS								
Psilate long cell rod	3081	1352	160599	8692	31712	1414	9970	7522
Echinate long cell rod	3081	0	133833	1087	9061	16967	14955	684
Cylindric psilate long cell	513	0	0	0	0	0	0	0
Psilate assymetrical LC	13863	4563	160599	23904	37752	7777	7477	14361
Echinate assymetrical LC	3081	338	93683	2173	7550	0	831	684
Psilate LC w/projections on 1 side	1027	1183	0	1087	3020	2828	4985	2735
Prickle hairs	3594	0	214132	7606	9061	0	0	2735
Tricomes	10783	2366	53533	9779	12081	8483	2492	4787
Hairs	513	169	66916	0	4530	2828	2492	2052
Bulliforms	10783	3211	107066	14125	12081	2828	4985	7522
?Bulliforms (echinate semi-sphere)	513	0	13383	0	0	0	0	684
Stomata	0	0	26767	0	3020	0	0	0
Tetracytic stomata (?Scirpus)	0	0	0	0	0	0	0	0
Sedge cones	9242	2704	816379	30423	49833	31813	29910	25987
Globular echinate cf date palm	0	1183	0	0	1510	3535	4985	684
Globular spinulose cf Doum palm	0	0	0	0	0	0	0	0
Globular verrucate (large)	0	0	0	0	0	0	0	0
Trapezoid	4108	2197	40150	10865	9061	10604	26586	6155
Indet monocot SC	5648	0	133833	9779	16611	14139	0	3419
TOTAL MONOCOT SINGLE CELLS	183305	71313	4817973	374856	530044	277833	331500	234563
MULTICELLS								
Silica skeleton psilate LC	6018	3466	565071	2732	4151	35348	22432	2645
Silica skeleton sinuate LC	334	495	59481	455	304	7070	9139	0
Silica skeleton echinate LC	167	495	29741	114	0	3535	0	331
Indet monocot leaf/stem	2675	0	446109	1594	709	35348	0	661
Silica skelton LC and stomata	167	0	0	0	0	0	831	0

Site: HT onsite samples								
Sample	SC149-4	S01-8	SC160-6	SC517-1	SC551-1	SC569-1	SC148-7	SC607-1
SINGLE CELLS								
Psilate long cell rod	65564	7188	34600	100410	15046	15743	20832	17434
Echinate long cell rod	0	1797	10646	13517	1038	4255	8152	8394
Cylindric psilate long cell	0	0	0	0	0	0	0	0
Psilate assymetrical LC	50663	37739	50569	79169	16083	5957	35323	16788
Echinate assymetrical LC	0	3594	10646	3862	1556	1276	5434	0
Psilate LC w/projections on 1 side	8941	0	5323	27033	0	3404	6340	5811
Prickle hairs	26822	8986	15969	0	2594	1276	1811	0
Tricomes	35762	17971	31938	27033	4669	8935	9057	1291
Hairs	14901	3594	10646	1931	519	851	906	646
Bulliforms	35762	26957	21292	17379	12452	3404	4529	2583
?Bulliforms (echinate semi-sphere)	2980	1797	2662	1931	519	0	0	0
Stomata	2980	0	0	0	0	0	0	2583
Tetracytic stomata (?Scirpus)	0	0	2662	0	0	0	0	0
Sedge cones	107287	43130	63876	65653	9858	3829	25360	23891
Globular echinate cf date palm	0	0	0	0	0	0	0	1937
Globular spinulose cf Doum palm	0	0	0	0	0	0	0	0
Globular verrucate (large)	0	0	0	0	0	0	0	0
Trapezoid	23841	41333	7985	17379	5707	6808	9963	9685
Indet monocot SC	32782	8986	7985	9655	5707	425	7246	646
TOTAL MONOCOT SINGLE CELLS	1075845	681102	958142	803279	191443	168918	366819	235031
MULTICELLS								
Silica skeleton psilate LC	59604	2143	95149	81100	753	2799	2415	5149
Silica skeleton sinuate LC	9934	0	36596	5793	125	816	242	468
Silica skeleton echinate LC	1987	138	0	5793	157	0	403	936
Indet monocot leaf/stem	37749	829	80511	11586	157	3032	242	12639
Silica skelton LC and stomata	0	0	0	0	0	233	0	468

Site: HT onsite samples								
Sample	**SC550-1**	**SC624-1**	**SC624-2**	**SC624-3**	**SC625-1**	**SC625-2**	**SC626-2**	**SC606-1**
SINGLE CELLS								
Psilate long cell rod	15523	11553	207338	16258	617	2676	9993	18682
Echinate long cell rod	18110	5777	14299	15445	308	1720	14605	2669
Cylindric psilate long cell	0	0	0	0	0	0	0	0
Psilate assymetrical LC	6037	4201	285984	14632	1233	956	3075	19572
Echinate assymetrical LC	5174	3151	35748	5690	88	573	3843	1779
Psilate LC w/projections on 1 side	6899	2626	7150	2439	132	1912	3843	1779
Prickle hairs	0	0	35748	2439	352	0	0	6227
Tricomes	7761	2626	35748	6503	749	1338	3843	10675
Hairs	862	1050	21449	1626	44	382	769	5338
Bulliforms	16385	3151	78645	9755	352	3250	6918	6227
?Bulliforms (echinate semi-sphere)	0	0	0	0	44	0	0	1779
Stomata	0	1575	7150	0	176	0	0	0
Tetracytic stomata (?Scirpus)	0	0	0	0	0	0	0	0
Sedge cones	37082	19431	243086	29264	1013	6691	16911	37364
Globular echinate cf date palm	5174	2101	0	813	44	1529	8455	0
Globular spinulose cf Doum palm	0	0	0	0	0	0	0	0
Globular verrucate (large)	0	0	0	0	0	0	0	0
Trapezoid	32770	14179	64346	10568	1145	4397	13836	13344
Indet monocot SC	0	0	35748	11381	264	0	0	1779
TOTAL MONOCOT SINGLE CELLS	326838	190630	2623899	303212	16429	64230	267494	323820
MULTICELLS								
Silica skeleton psilate LC	4190	10503	74911	3322	349	1314	2182	6066
Silica skeleton sinuate LC	466	4774	5549	289	55	179	1511	243
Silica skeleton echinate LC	698	955	2774	289	37	179	336	728
Indet monocot leaf/stem	0	33419	11098	722	257	0	4028	1698
Silica skelton LC and stomata	233	955	0	144	0	0	168	485

Site: HT onsite samples						
Sample	**SC606-2**	**SC615-1**	**S01-7a**	**S01-7b**	**S01-6**	**S01-6a**
SINGLE CELLS						
Psilate long cell rod	2649	21197	4859	14088	10870	26688
Echinate long cell rod	1766	8328	3887	10175	1359	12454
Cylindric psilate long cell	0	0	0	0	0	0
Psilate assymetrical LC	4710	12870	13118	6262	29893	16013
Echinate assymetrical LC	1178	1514	0	0	2718	0
Psilate LC w/projections on 1 side	1178	9842	1943	5479	1359	3558
Prickle hairs	2061	0	14090	11740	9511	5338
Tricomes	4416	9085	9717	5479	12229	24909
Hairs	2061	0	0	2348	0	3558
Bulliforms	6771	13627	13118	8610	17664	14234
?Bulliforms (echinate semi-sphere)	589	0	0	0	0	0
Stomata	0	0	0	783	0	0
Tetracytic stomata (?Scirpus)	0	0	0	0	0	0
Sedge cones	8831	19683	17977	40700	38046	65831
Globular echinate cf date palm	589	2271	0	783	0	0
Globular spinulose cf Doum palm	0	0	0	0	0	0
Globular verrucate (large)	0	0	0	0	0	0
Trapezoid	3238	20440	2915	7827	13588	21350
Indet monocot SC	1472	12870	3401	9392	12229	24909
TOTAL MONOCOT SINGLE CELLS	107449	293734	192884	317771	468779	708123
MULTICELLS						
Silica skeleton psilate LC	4810	3909	1039	0	3416	8116
Silica skeleton sinuate LC	301	711	649	3972	569	11362
Silica skeleton echinate LC	601	711	260	1986	142	4869
Indet monocot leaf/stem	1804	9950	2338	14894	1993	21101
Silica skelton LC and stomata	0	0	0	0	0	0

Site: HT onsite samples								
Sample	SC19-1	SC8-1	SC99-1	SC147-1	SC147-2	SC518-2	SC518-3	SC149-2
MULTICELLS								
leaf/stem with grass stomata	0	99	0	0	0	7070	831	0
leaf/stem with rondels	167	0	89222	228	0	0	0	0
leaf/stem with bilobes indet	0	0	0	0	0	0	831	0
leaf/stem with chloridoid bilobes	0	0	0	0	0	0	0	0
leaf/stem with panicoid bilobes	0	0	0	0	0	0	0	0
leaf/stem with arunidoid bilobes	0	0	0	0	0	0	0	0
Phragmite leaf	0	0	0	114	0	0	0	0
phragmite stem	0	0	0	0	0	0	831	0
leaf/stem with saddles indet	0	0	29741	0	0	0	0	0
leaf/stem with choridoid saddles	0	0	0	0	0	0	0	0
leaf/stem with arunidoid saddles	0	0	0	0	0	0	0	0
leaf/stem with quadralobes	0	0	0	0	0	0	0	0
leaf/stem with bulliforms	167	0	118962	683	101	0	0	110
leaf/stem with crenates	0	0	0	0	0	0	0	0
square cell leaf/stem	0	297	0	0	0	0	2492	0
multiple bulliforms	502	0	29741	683	101	0	0	220
Stem with hair	334	0	0	114	0	0	0	220
Assymetrical LCs	1170	1287	178443	1707	1316	10604	4985	1433
Cylindrical (rods) and LCs	1337	792	118962	1138	1519	17674	4985	2094
Sedge cones	167	198	118962	114	304	7070	831	331
Visible mesophyll	334	0	0	0	0	7070	831	110
Indet husk	0	1882	178443	114	202	56556	9970	661
Wheat husk indet	0	396	89222	0	0	3535	831	0
Emmer wheat	0	0	0	0	0	0	0	0
Durum wheat	0	0	0	0	0	0	0	0
Einkorn wheat	0	0	0	0	0	0	0	0

Site: HT onsite samples								
Sample	SC149-4	S01-8	SC160-6	SC517-1	SC551-1	SC569-1	SC148-7	SC607-1
MULTICELLS								
leaf/stem with grass stomata	0	0	0	0	0	0	0	0
leaf/stem with rondels	0	69	14638	5793	31	233	81	0
leaf/stem with bilobes indet	0	69	7319	0	0	0	0	0
leaf/stem with chloridoid bilobes	0	0	0	0	0	0	0	0
leaf/stem with panicoid bilobes	0	0	0	0	0	0	0	0
leaf/stem with arunidoid bilobes	0	0	0	0	0	0	0	0
Phragmite leaf	0	0	0	0	0	233	0	0
phragmite stem	0	0	0	1931	0	0	0	468
leaf/stem with saddles indet	0	0	0	0	0	0	0	0
leaf/stem with choridoid saddles	0	0	0	0	0	0	0	0
leaf/stem with arunidoid saddles	0	0	0	0	0	0	0	0
leaf/stem with quadralobes	0	0	0	0	0	0	0	0
leaf/stem with bulliforms	3974	346	7319	3862	220	117	322	0
leaf/stem with crenates	0	0	0	0	0	0	81	0
square cell leaf/stem	0	0	14638	3862	31	233	0	0
multiple bulliforms	0	484	0	0	94	233	81	0
Stem with hair	1987	69	14638	5793	0	0	81	0
Assymetrical LCs	13908	899	73191	3862	502	1516	1932	468
Cylindrical (rods) and LCs	21855	829	109787	9655	753	583	1127	3277
Sedge cones	9934	0	51234	23172	63	0	81	2341
Visible mesophyll	0	0	7319	0	31	0	0	468
Indet husk	7947	276	65872	0	94	583	725	4213
Wheat husk indet	0	0	0	0	0	0	0	468
Emmer wheat	0	0	0	0	0	0	0	0
Durum wheat	0	0	0	0	0	0	0	0
Einkorn wheat	0	0	0	0	0	0	0	0

Site: HT onsite samples								
Sample	SC550-1	SC624-1	SC624-2	SC624-3	SC625-1	SC625-2	SC626-2	SC606-1
MULTICELLS								
leaf/stem with grass stomata	0	2864	0	0	0	60	168	0
leaf/stem with rondels	0	0	19421	0	0	0	0	243
leaf/stem with bilobes indet	0	1910	0	0	0	119	168	0
leaf/stem with chloridoid bilobes	0	0	0	0	0	0	0	0
leaf/stem with panicoid bilobes	0	0	0	0	0	0	0	0
leaf/stem with arunidoid bilobes	0	0	0	0	0	0	0	0
Phragmite leaf	466	0	0	0	18	60	0	0
phragmite stem	0	0	0	0	18	0	0	0
leaf/stem with saddles indet	0	955	0	0	0	0	336	0
leaf/stem with choridoid saddles	0	0	0	0	0	0	0	0
leaf/stem with arunidoid saddles	0	0	0	0	0	0	0	0
leaf/stem with quadralobes	0	0	0	0	0	0	0	0
leaf/stem with bulliforms	0	0	16647	433	92	0	0	243
leaf/stem with crenates	0	0	0	0	0	0	0	0
square cell leaf/stem	233	0	0	0	0	119	0	0
multiple bulliforms	0	0	5549	433	55	0	168	485
Stem with hair	0	0	2774	289	0	0	0	0
Assymetrical LCs	3026	7639	49940	2600	257	657	839	1456
Cylindrical (rods) and LCs	1630	6684	38843	2022	92	478	1846	6066
Sedge cones	1630	955	8323	289	110	0	0	1941
Visible mesophyll	466	1910	2774	289	18	239	0	485
Indet husk	931	8593	8323	867	550	478	1175	485
Wheat husk indet	0	0	0	0	0	0	0	243
Emmer wheat	0	0	0	0	0	0	0	0
Durum wheat	0	0	0	0	0	0	0	0
Einkorn wheat	0	0	0	0	0	0	0	0

Site: HT onsite samples						
Sample	**SC606-2**	**SC615-1**	**S01-7a**	**S01-7b**	**S01-6**	**S01-6a**
MULTICELLS						
leaf/stem with grass stomata	0	0	0	0	0	0
leaf/stem with rondels	150	0	0	0	285	0
leaf/stem with bilobes indet	0	0	0	1986	0	0
leaf/stem with chloridoid bilobes	0	0	0	0	0	0
leaf/stem with panicoid bilobes	0	0	0	0	0	0
leaf/stem with arunidoid bilobes	0	0	0	0	0	0
Phragmite leaf	0	0	0	0	142	0
phragmite stem	0	355	0	0	0	0
leaf/stem with saddles indet	0	355	520	2979	0	8116
leaf/stem with choridoid saddles	0	0	0	0	0	0
leaf/stem with arunidoid saddles	0	0	0	0	0	0
leaf/stem with quadralobes	0	0	0	0	0	0
leaf/stem with bulliforms	301	0	260	0	854	4869
leaf/stem with crenates	0	0	0	0	0	0
square cell leaf/stem	0	0	0	4965	0	4869
multiple bulliforms	0	0	130	1986	854	1623
Stem with hair	150	0	909	0	142	3246
Assymetrical LCs	1503	711	2208	15887	2135	32463
Cylindrical (rods) and LCs	1353	3553	909	6951	1423	6493
Sedge cones	902	711	779	5958	142	1623
Visible mesophyll	451	0	0	0	0	4869
Indet husk	601	2132	779	9930	142	11362
Wheat husk indet	0	0	0	993	0	1623
Emmer wheat	0	0	0	0	0	0
Durum wheat	0	0	0	0	0	0
Einkorn wheat	0	0	0	0	0	0

Site: HT onsite samples								
Sample	SC19-1	SC8-1	SC99-1	SC147-1	SC147-2	SC518-2	SC518-3	SC149-2
MULTICELLS								
Bread wheat	0	0	0	0	0	0	0	0
Barley husk	0	396	0	0	0	31813	10801	0
Cereal straw	0	198	29741	0	202	10604	4154	441
Awn	0	0	148703	114	304	21209	4154	331
Papillae aggragation (distal)	0	396	118962	0	101	49487	13293	0
Setaria	0	0	29741	0	0	0	0	0
Aegilops (goat grass)	167	0	89222	0	101	0	0	0
Bromus	0	0	0	0	0	0	0	110
Avena (oat grass)	0	0	0	0	0	0	0	0
Lolium (rye grass)	0	0	0	0	0	0	0	0
Scirpus type (tetracytic stomata)	0	0	0	0	0	0	0	0
Wild grass husk	1505	396	178443	114	304	0	0	110
Stem (indet grass)	334	0	0	114	0	0	0	110
panicoid bilobes	0	0	0	0	0	7070	0	0
Indet MC	334	0	178443	455	101	38883	0	331
TOTAL MONOCOT MULTICELLS	15881	10794	2825354	10586	9820	349943	92222	10251
TOTAL MONOCOTS	199186	82107	7643327	385442	539864	627776	423722	244814
DICOTS								
SINGLE CELLS								
Globular psilate	1027	676	53533	3260	1510	1414	2492	1368
Globular multifaceted	0	0	0	0	0	0	0	0
Globular verrucate (small)	0	0	40150	4346	3020	0	0	2052
Dicot elongate (oblong)	1027	0	13383	0	7550	0	0	684
Tracheid	513	169	80300	1087	3020	9190	831	0
Blocks	513	0	0	0	0	0	0	0
Platey	0	0	0	0	0	0	0	0

Site: HT onsite samples								
Sample	SC149-4	S01-8	SC160-6	SC517-1	SC551-1	SC569-1	SC148-7	SC607-1
MULTICELLS								
Bread wheat	0	0	0	0	0	0	0	0
Barley husk	0	0	0	0	0	0	0	936
Cereal straw	3974	69	7319	0	0	0	81	1873
Awn	1987	0	0	0	0	233	0	936
Papillae aggragation (distal)	0	0	0	0	0	0	0	2341
Setaria	0	0	0	0	0	0	0	0
Aegilops (goat grass)	0	0	0	0	0	0	0	0
Bromus	0	0	0	0	0	0	81	0
Avena (oat grass)	0	0	0	0	0	0	0	0
Lolium (rye grass)	0	0	0	0	0	0	0	0
Scirpus type (tetracytic stomata)	0	69	7319	0	0	0	0	0
Wild grass husk	7947	69	43915	3862	63	700	322	936
Stem (indet grass)	3974	138	7319	3862	0	117	0	0
panicoid bilobes	0	0	0	0	0	0	0	0
Indet MC	7947	69	29277	11586	125	0	242	2809
TOTAL MONOCOT MULTICELLS	194705	6566	673361	181510	3199	11663	8534	41195
TOTAL MONOCOTS	1270551	687668	1631503	984789	194642	180582	375353	276226
DICOTS								
SINGLE CELLS								
Globular psilate	0	1797	0	0	519	0	0	0
Globular multifaceted	0	0	0	0	0	0	0	0
Globular verrucate (small)	2980	1797	13308	0	0	0	1814	0
Dicot elongate (oblong)	0	0	5323	11586	2075	1276	0	0
Tracheid	11921	3594	5323	0	0	0	3623	14205
Blocks	2980	0	0	0	0	425	0	0
Platey	0	0	0	0	0	0	0	0

Site: HT onsite samples								
Sample	**SC550-1**	**SC624-1**	**SC624-2**	**SC624-3**	**SC625-1**	**SC625-2**	**SC626-2**	**SC606-1**
MULTICELLS								
Bread wheat	0	0	0	0	0	0	0	0
Barley husk	233	3819	0	0	0	358	336	0
Cereal straw	698	4774	2774	0	18	299	504	243
Awn	931	2864	2774	433	18	358	504	243
Papillae aggragation (distal)	2328	955	0	0	18	538	504	0
Setaria	0	0	0	0	0	0	0	0
Aegilops (goat grass)	0	0	0	0	37	0	0	0
Bromus	0	0	0	144	0	0	0	0
Avena (oat grass)	0	0	0	0	0	0	0	243
Lolium (rye grass)	0	0	0	0	55	0	0	0
Scirpus type (tetracytic stomata)	0	0	0	144	0	0	0	0
Wild grass husk	0	5729	0	1155	18	179	1007	970
Stem (indet grass)	0	0	2774	144	73	0	0	0
panicoid bilobes	0	0	0	0	0	0	168	0
Indet MC	0	0	13872	867	0	0	0	728
TOTAL MONOCOT MULTICELLS	18157	100256	269123	14876	2146	5615	15946	23292
TOTAL MONOCOTS	344996	290886	2893023	318088	18575	69845	283440	347112
DICOTS								
SINGLE CELLS								
Globular psilate	5174	2626	14299	0	0	1529	1537	890
Globular multifaceted	0	0	0	0	0	0	0	0
Globular verrucate (small)	0	0	0	2439	132	0	769	0
Dicot elongate (oblong)	0	0	7150	0	44	0	0	2669
Tracheid	0	3676	21449	813	220	956	6149	890
Blocks	0	525	0	0	44	0	3075	890
Platey	0	0	0	0	0	0	0	0

Site: HT onsite samples						
Sample	SC606-2	SC615-1	S01-7a	S01-7b	S01-6	S01-6a
MULTICELLS						
Bread wheat	0	0	0	0	0	0
Barley husk	0	711	0	0	0	1623
Cereal straw	150	711	130	1986	0	4869
Awn	301	711	0	7944	142	4869
Papillae aggragation (distal)	0	711	0	2979	0	0
Setaria	0	0	0	0	0	0
Aegilops (goat grass)	0	0	0	0	0	0
Bromus	0	0	0	0	0	0
Avena (oat grass)	0	0	0	0	0	0
Lolium (rye grass)	0	0	0	0	0	0
Scirpus type (tetracytic stomata)	0	0	0	0	0	0
Wild grass husk	451	711	260	2979	142	0
Stem (indet grass)	150	0	130	993	142	0
panicoid bilobes	0	0	0	0	0	0
Indet MC	451	4620	1948	18866	569	19478
TOTAL MONOCOT MULTICELLS	14431	31271	13250	108233	13238	157444
TOTAL MONOCOTS	121880	325005	206134	426004	482017	865567
DICOTS						
SINGLE CELLS						
Globular psilate	0	2271	1458	1565	4076	0
Globular multifaceted	0	0	0	0	0	0
Globular verrucate (small)	589	0	0	0	5435	0
Dicot elongate (oblong)	883	0	486	0	0	1779
Tracheid	883	9842	7288	1565	1359	35584
Blocks	0	2271	0	0	0	0
Platey	0	0	0	0	0	0

Site: HT onsite samples								
Sample	SC19-1	SC8-1	SC99-1	SC147-1	SC147-2	SC518-2	SC518-3	SC149-2
SINGLE CELLS								
Sheet - clear (platelet)	1540	507	80300	4346	3020	1414	1662	4787
Sheet - scrobiculate	2054	0	13383	0	3020	0	0	684
Sheet - spotted	513	0	0	1087	0	0	0	1368
Sheet - striated	0	0	0	0	0	0	0	0
Tricomes (cf Metcalfe)	0	0	0	0	0	0	0	0
Opaque platelets (Bozarth)	0	0	0	0	0	0	0	0
solid opaque platelets	0	0	0	0	0	0	0	0
Single polyhedral (Bozarth)	9756	3211	147216	34769	45303	2121	6647	17096
Decorated polyhedral (4-8 sides)	0	0	0	1087	3020	0	0	1368
Single jigsaw	2567	1859	80300	7606	7550	1414	2492	8890
Verrucate	513	507	0	4346	0	4949	0	3419
Stipa type rondel	0	0	0	0	0	0	0	0
Scalloped (round)	0	0	0	0	0	0	0	0
Scalloped (see Bozarth)	2567	169	13383	0	10571	0	0	2052
Pinaceae tracheids	0	0	0	0	0	0	0	0
Irregular echinate LC	0	0	0	0	0	0	0	0
Conifer blocky polyhedral (>8 side)	0	0	0	0	0	0	0	0
Sclereid	2054	0	240899	2173	6040	0	0	2052
Astrosclereid	0	0	0	0	0	0	0	0
large sphere (holes)	0	0	0	0	0	0	0	0
Stellate	0	0	0	0	0	0	0	0
Indet dicot SC	0	0	53533	0	10571	0	0	2735
TOTAL DICOT SINGLE CELLS	24646	7097	816379	64106	104197	20502	14124	48554
MULTICELLS								
Multi LCs	0	0	0	0	0	0	0	0
Multiple jigsaws	0	1089	29741	0	0	0	4154	0

Site: HT onsite samples								
Sample	SC149-4	S01-8	SC160-6	SC517-1	SC551-1	SC569-1	SC148-7	SC607-1
SINGLE CELLS								
Sheet - clear (platelet)	11921	17971	5323	0	2594	0	2717	0
Sheet - scrobiculate	0	0	0	0	519	0	0	0
Sheet - spotted	5960	10783	7985	0	0	0	906	0
Sheet - striated	0	0	0	0	0	0	0	0
Tricomes (cf Metcalfe)	0	0	0	0	0	0	0	0
Opaque platelets (Bozarth)	0	0	0	0	0	0	0	0
solid opaque platelets	0	0	0	0	0	0	0	0
Single polyhedral (Bozarth)	50663	50319	53230	9655	10895	1276	26266	3228
Decorated polyhedral (4-8 sides)	2980	10783	2662	0	3113	0	906	0
Single jigsaw	11921	12580	21292	11586	3113	425	9963	646
Verrucate	8941	1797	0	0	3113	1276	906	2583
Stipa type rondel	0	0	0	0	0	0	0	0
Scalloped (round)	0	0	0	0	0	0	0	0
Scalloped (see Bozarth)	2980	0	0	0	0	0	906	2583
Pinaceae tracheids	0	0	0	0	0	0	0	0
Irregular echinate LC	0	0	5323	15448	0	2127	0	0
Conifer blocky polyhedral (>8 side)	0	0	0	0	0	0	0	0
Sclereid	2980	0	5323	0	2075	0	0	0
Astrosclereid	0	0	0	0	0	0	0	0
large sphere (holes)	0	0	0	0	0	0	0	0
Stellate	0	0	0	0	0	0	0	0
Indet dicot SC	0	0	5323	0	2594	2127	1811	0
TOTAL DICOT SINGLE CELLS	116227	111420	130414	48273.977	30610.1497	8935	49818	23245
MULTICELLS								
Multi LCs	0	0	0	0	31	0	0	468
Multiple jigsaws	0	0	0	1931	0	0	161	468

Site: HT onsite samples								
Sample	SC550-1	SC624-1	SC624-2	SC624-3	SC625-1	SC625-2	SC626-2	SC606-1
SINGLE CELLS								
Sheet - clear (platelet)	0	0	35748	3252	0	573	1537	4448
Sheet - scrobiculate	0	0	0	0	0	0	0	0
Sheet - spotted	3449	0	7150	0	0	0	0	890
Sheet - striated	0	0	0	0	0	0	0	0
Tricomes (cf Metcalfe)	0	0	0	0	44	0	0	0
Opaque platelets (Bozarth)	0	0	0	0	0	0	0	0
solid opaque platelets	0	0	0	0	44	0	0	0
Single polyhedral (Bozarth)	11211	8928	121543	19510	352	3059	23828	18682
Decorated polyhedral (4-8 sides)	0	0	14299	813	44	0	0	1779
Single jigsaw	1725	1050	50047	11381	264	2103	6149	1779
Verrucate	0	3676	0	0	0	3059	1537	3558
Stipa type rondel	0	0	0	0	0	0	0	0
Scalloped (round)	0	0	0	0	0	1720	0	0
Scalloped (see Bozarth)	1725	1575	0	0	0	956	769	0
Pinaceae tracheids	0	0	0	0	0	0	0	0
Irregular echinate LC	0	0	0	0	220	0	0	0
Conifer blocky polyhedral (>8 side)	0	0	0	0	0	0	0	0
Sclereid	0	0	14299	813	0	0	0	0
Astrosclereid	0	0	0	0	0	0	0	0
large sphere (holes)	0	0	0	0	0	0	0	0
Stellate	0	0	0	0	0	0	0	0
Indet dicot SC	0	1575	0	4877	88	0	1537	0
TOTAL DICOT SINGLE CELLS	23284	23632	285984	43897	1498	13955	46888	36474
MULTICELLS								
Multi LCs	0	0	0	0	0	0	336	0
Multiple jigsaws	466	0	0	0	0	478	336	0

Site: HT onsite samples						
Sample	SC606-2	SC615-1	S01-7a	S01-7b	S01-6	S01-6a
SINGLE CELLS						
Sheet - clear (platelet)	1178	0	0	0	5435	0
Sheet - scrobiculate	0	0	0	0	0	0
Sheet - spotted	589	0	0	0	1359	0
Sheet - striated	0	0	0	0	0	0
Tricomes (cf Metcalfe)	0	0	0	0	0	0
Opaque platelets (Bozarth)	0	0	0	0	0	0
solid opaque platelets	0	0	486	0	0	0
Single polyhedral (Bozarth)	9420	7570	0	0	43481	0
Decorated polyhedral (4-8 sides)	883	0	0	0	1359	0
Single jigsaw	2355	757	0	0	9511	0
Verrucate	294	5299	0	783	5435	0
Stipa type rondel	0	0	0	0	0	0
Scalloped (round)	0	0	0	0	0	0
Scalloped (see Bozarth)	589	1514	0	0	0	0
Pinaceae tracheids	0	0	0	0	0	0
Irregular echinate LC	294	0	0	0	0	0
Conifer blocky polyhedral (>8 side)	0	0	0	0	0	0
Sclereid	294	0	0	0	2718	0
Astrosclereid	0	0	0	0	0	0
large sphere (holes)	0	0	0	0	0	0
Stellate	0	0	0	0	0	0
Indet dicot SC	589	0	0	0	0	0
TOTAL DICOT SINGLE CELLS	18840	29525	9717	3913	80168	37363.2649
MULTICELLS						
Multi LCs	0	355	0	0	0	1623
Multiple jigsaws	0	0	0	0	0	0

Site: HT onsite samples								
Sample	SC19-1	SC8-1	SC99-1	SC147-1	SC147-2	SC518-2	SC518-3	SC149-2
MULTICELLS								
polyhedral (Bozarth)	0	99	0	114	202	3535	831	110
decorated polyhedral (4-8 sides)	0	0	0	0	0	0	0	0
Hairbase	0	0	0	0	0	0	0	0
cf oak	0	0	0	341	0	0	0	441
Silica aggregates	836	99	29741	341	0	0	831	0
Palisade/mesophyll (Bozarth)	0	0	0	0	0	0	0	0
Favose (large)	334	0	0	0	0	0	0	110
Favose (small)	0	0	0	0	0	0	0	110
Honeycomb favose	0	0	0	0	0	0	0	0
Indet dicot multicell	0	0	148703	114	202	3535	831	220
?Vitis sp	0	0	29741	0	0	0	0	0
TOTAL DICOT MULTICELLS	1170	1287	237925	911	405	7070	6647	992
TOTAL DICOTS	25816	8385	1054303	65016	104602	27571	20771	49546
OTHER								
Very long sinuate LC (fern)	0	0	0	0	0	0	0	0
Stomata with uneven dentritic LC	0	0	0	0	0	0	0	0
Sponge spicules	0	0	0	0	0	0	0	0
Diatoms	3081	3380	53533	8692	99666	0	1662	4787
SAMPLE NO AND DATING	**SC19-1: EBA under floor SC08**	**SC8-1:EBA floor C14**	**SC99-1: MBA AC transect Ashy dep on street**	**SC147-1: MBA Transect AC tannour fill**	**SC147-2: MBA AC transect Tannour fill**	**SC518-2: burn from floor 408 MBA piazza**	**SC518-3: MBA piazza**	**SC149-2: MBA basin fill**

Site: HT onsite samples								
Sample	SC149-4	S01-8	SC160-6	SC517-1	SC551-1	SC569-1	SC148-7	SC607-1
MULTICELLS								
polyhedral (Bozarth)	1987	207	21957	1931	31	0	81	936
decorated polyhedral (4-8 sides)	0	0	0	0	0	0	0	0
Hairbase	0	69	0	1931	31	0	81	0
cf oak	0	69	14638	0	0	0	0	0
Silica aggregates	0	69	14638	9655	31	117	0	468
Palisade/mesophyll (Bozarth)	0	0	0	0	0	0	0	0
Favose (large)	0	0	0	0	0	0	0	0
Favose (small)	0	0	7319	0	0	0	0	0
Honeycomb favose	0	0	0	0	0	0	0	0
Indet dicot multicell	1987	0	29277	0	63	0	161	1404
?Vitis sp	1987	0	0	1931	0	0	0	468
TOTAL DICOT MULTICELLS	5960	415	87830	17379	188	117	483	4213
TOTAL DICOTS	122187	111835	218243	65653	30798	9052	50301	27458
OTHER								
Very long sinuate LC (fern)	0	0	0	3862	0	851	0	0
Stomata with uneven dentritic LC	0	0	0	0	0	0	0	0
Sponge spicules	0	0	0	0	0	425	0	0
Diatoms	2980	5391	10646	5793	4151	12339	12680	0
SAMPLE NO AND DATING	**SC149-4: MBA deposit on basin**	**S01-8: fill above 518/408; from cut**	**SC160-6: Ashy layer on top of Piazza**	**SC517-1: MBA floor room 52/bldg G**	**SC551-1: MBA mudbrick room 52/bldg G**	**SC569-1: MBA destruction 52/G**	**SC148-7: MBA room 55 collapse**	**SC607-1: MBA pebble floor Bldg Q**

Site: HT onsite samples								
Sample	**SC550-1**	**SC624-1**	**SC624-2**	**SC624-3**	**SC625-1**	**SC625-2**	**SC626-2**	**SC606-1**
MULTICELLS								
polyhedral (Bozarth)	233	1910	0	0	18	0	336	0
decorated polyhedral (4-8 sides)	0	0	0	0	0	0	0	0
Hairbase	0	0	0	0	18	0	0	0
cf oak	0	0	0	0	0	0	0	485
Silica aggregates	1630	0	13872	433	37	0	0	728
Palisade/mesophyll (Bozarth)	0	0	0	0	0	0	0	0
Favose (large)	0	0	0	0	0	0	0	0
Favose (small)	0	0	0	0	0	0	0	0
Honeycomb favose	0	0	0	0	0	0	0	0
Indet dicot multicell	233	0	8323	289	92	60	168	0
?Vitis sp	0	0	2774	0	18	0	0	0
TOTAL DICOT MULTICELLS	2561	1910	24970	722	183	538	1175	1213
TOTAL DICOTS	25845	25541	310954	44619	1681	14492	48063	37687
OTHER								
Very long sinuate LC (fern)	0	0	0	0	0	0	0	0
Stomata with uneven dentritic LC	0	0	0	0	0	0	0	0
Sponge spicules	0	0	7150	0	44	0	0	0
Diatoms	0	0	14299	17071	308	0	0	3558
SAMPLE NO AND DATING	**SC550-1: MBA flag floor Bldg Q**	**SC624-1: MBA tannour right Bldg Q**	**SC624-2: MBA tannour left Bldg Q**	**SC624-3: MBA tannour Bldg Q**	**SC6 25-1: MBA hearth Bldg Q**	**SC625-2: MBA hearth bldg Q**	**SC626-2: MBA hearth bldg Q**	**SC606-1: MBA ?door socket**

Site: HT onsite samples						
Sample	SC606-2	SC615-1	S01-7a	S01-7b	S01-6	S01-6a
MULTICELLS						
polyhedral (Bozarth)	301	355	0	993	142	0
decorated polyhedral (4-8 sides)	150	0	0	0	0	0
Hairbase	0	711	0	0	0	0
cf oak	150	0	0	0	427	0
Silica aggregates	301	711	0	0	427	0
Palisade/mesophyll (Bozarth)	0	0	0	0	0	0
Favose (large)	0	0	0	0	0	0
Favose (small)	0	0	0	0	0	0
Honeycomb favose	0	0	0	0	0	0
Indet dicot multicell	0	0	0	993	142	0
?Vitis sp	0	0	0	0	0	0
TOTAL DICOT MULTICELLS	902	2132	0	1986	1139	1623
TOTAL DICOTS	19742	31657	9717	5899	81307	38986
OTHER						
Very long sinuate LC (fern)	0	0	0	0	0	0
Stomata with uneven dentritic LC	0	0	0	0	0	0
Sponge spicules	0	0	0	0	0	0
Diatoms	2649	0	0	0	10870	0
SAMPLE NO AND DATING	**SC606-2: MBA ?door socket**	**SC615-1: MBA groundstone, courtyard 24**	**S01-7a: MBA-LBA**	**S01-7b: MBA-LBA**	**S01-6: LBA fill ass. W/ fill 496**	**S01-6a: LBA ass. W/ fill 496 C14**

Site: HT onsite samples								
Sample	SC19-1	SC8-1	SC99-1	SC147-1	SC147-2	SC518-2	SC518-3	SC149-2
TOTAL SILICA CONTENT	2.6	1.6	27.4	23.2	2.1	6.4	5.4	4
TOTAL PHYTOLITHS	225002	90492	8697630	450459	644466	655347	444493	294360
TOTAL REEDS/PHRAGMITES	0	0	0	114	0	7070	831	0
TOTAL SEDGES	1839	990	237925	1252	1822	31813	6647	2535
TOTAL WETLAND PLANTS	1839	990	237925	1366	1822	38883	7477	2535
TOTAL WHEAT HUSKS	0	396	89222	0	0	3535	831	0
TOTAL CEREAL HUSKS	0	2674	267665	114	202	91904	21602	661
TOTAL CEREAL STRAW								
TOTAL CEREALS								
TOTAL WILD GRASS HUSKS	1672	396	267665	114	405	0	0	220
TOTAL GRASSES AND STRAW	8359	4654	921958	3415	5062	60091	36556	3417
Total wild grasses	8191	4456	981439	3529	4859	49487	32402	2866
TOTAL ?FRUIT	0	0	29741	1087	3020	0	0	1368
TOTAL LEAF	12836	6427	337555	43575	56076	16260	14955	26097
TOTAL BARK/wood	6484	1282	176956	9034	7550	2828	4985	8206
TOTAL DICOTS (ADJUSTED)	387240	125775	15,613,800	926355	1523715	413565	311565	311565
TOTAL DICOT SC (ADJUSTED)	369690	106462.055	12245680	961588	1562951	307525	211860.997	728307.692
TOTAL SINGLE CELLS	207951	78410	5634351	438962	634241	298335.015	345624	283117
TOTAL MULTICELLS	17052	12082	3063279	11497	10225	357012	98868	11243
Total rondels	35942	6928	1311559	81490	119298	33227	29079	47186
Total bilobes	0	1521	0	0	1510	2828	4154	0
Total saddles	513	2366	267665	3260	4530	5656	4154	1368

Site: HT onsite samples								
Sample	**SC149-4**	**S01-8**	**SC160-6**	**SC517-1**	**SC551-1**	**SC569-1**	**SC148-7**	**SC607-1**
TOTAL SILICA CONTENT	8.7	2.6	8.9	3.3	1.2	1.7	2.4	9.3
TOTAL PHYTOLITHS	1392738	799504	1849746	1050442	225441	189633	425654	303684
TOTAL REEDS/PHRAGMITES	0	0	0	1931	0	233	0	468
TOTAL SEDGES	31789	829	168340	32826	847	583	1208	6086
TOTAL WETLAND PLANTS	31789	829	168340	34757	847	816	1208	6554
TOTAL WHEAT HUSKS	0	0	0	0	0	0	0	468
TOTAL CEREAL HUSKS	7947	276	65872	0	94	583	725	5618
TOTAL CEREAL STRAW								
TOTAL CEREALS								
TOTAL WILD GRASS HUSKS	7947	69	43915	3862	63	700	403	936
TOTAL GRASSES AND STRAW	85432	2419	190298	94617	941	4432	3140	8426
Total wild grasses	77485	2281	190298	96548	972	4549	3140	6554
TOTAL ?FRUIT	4967	10783	2662	1931	3113	0	906	468
TOTAL LEAF	76491	66700	107126	40550	14039	3829	40093	19484
TOTAL BARK/wood	20861	30620	27946	9655	3663	542	3623	468
TOTAL DICOTS (ADJUSTED)	311565	311565	311565	311565	311565	311565	311565	311565
TOTAL DICOT SC (ADJUSTED)	1743406	1671305.95	1956206.31	724110	459152	134029	747267	348672.666
TOTAL SINGLE CELLS	1192072	792522	1088556	851553	222053	177854	416637	258276
TOTAL MULTICELLS	200666	6981	761190	198889	3387	11780	9017	45408
Total rondels	265236	197681	210259	160270	34242	22976	112310	38741
Total bilobes	2980	1797	5323	0	0	425	0	5166
Total saddles	2980	8986	2662	7724	0	851	906	7103

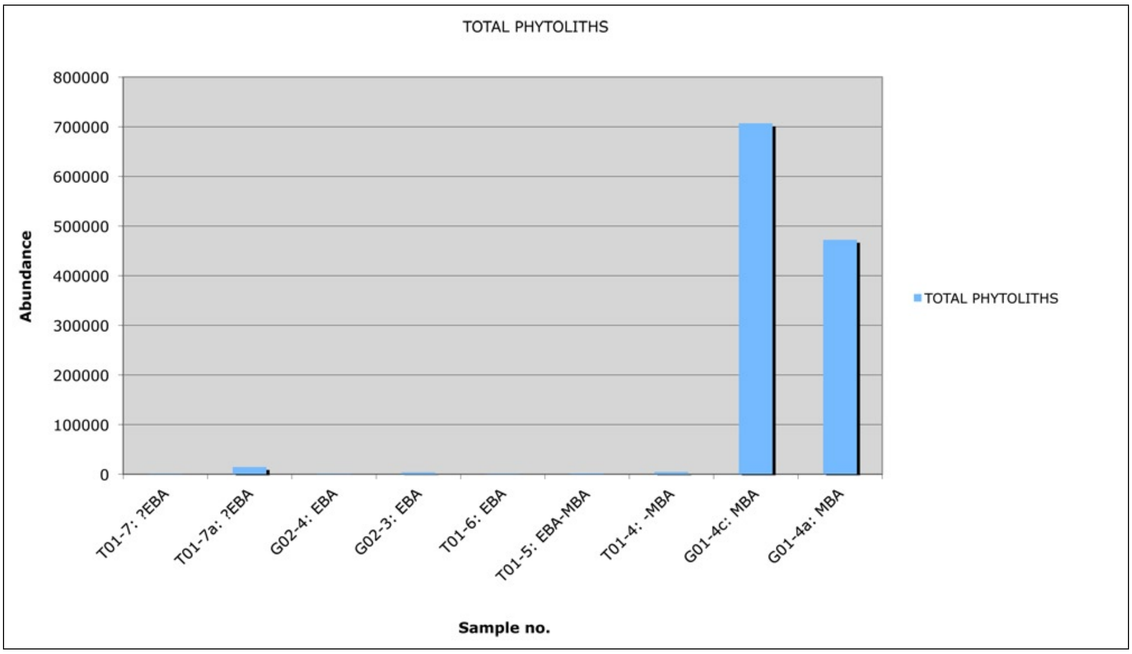
Site: HT onsite samples								
Sample	**SC550-1**	**SC624-1**	**SC624-2**	**SC624-3**	**SC625-1**	**SC625-2**	**SC626-2**	**SC606-1**
TOTAL SILICA CONTENT	6.1	5.4	10.6	5.2	0.5	1.2	5.8	3.3
TOTAL PHYTOLITHS	370840	316428	3203976	362707	20256	84338	331503	384800
TOTAL REEDS/PHRAGMITES	466	0	0	0	37	60	168	0
TOTAL SEDGES	3725	9548	49940	2600	220	717	1846	8492
TOTAL WETLAND PLANTS	4190	9548	49940	2600	257	777	2014	8492
TOTAL WHEAT HUSKS	0	0	0	0	0	0	0	243
TOTAL CEREAL HUSKS	1164	12413	8323	867	550	836	1511	728
TOTAL CEREAL STRAW								
TOTAL CEREALS								
TOTAL WILD GRASS HUSKS	0	5729	0	1300	110	179	1007	1213
TOTAL GRASSES AND STRAW	5354	28645	86008	5055	605	2031	5371	7764
Total wild grasses	4656	23871	99881	4910	514	1732	4868	7764
TOTAL ?FRUIT	0	0	17074	813	62	0	0	1779
TOTAL LEAF	13634	15564	193039	31703	1075	6595	36798	21351
TOTAL BARK/wood	10253	3151	71069	3685	125	2103	6149	7845
TOTAL DICOTS (ADJUSTED)	311565	311565	311565	311565	311565	311565	311565	311565
TOTAL DICOT SC (ADJUSTED)	349259.951	354477.352	4289753.47	658450.574	22463.0418	209321	703325	547114
TOTAL SINGLE CELLS	350122	214262	2909883	347109	17926	78185	314382	360295
TOTAL MULTICELLS	20718	102166	294094	15598	2330	6153	17121	24505
Total rondels	18972	27833	657762	59342	2114	6882	46120	79176
Total bilobes	12936	3151	21449	0	44	2103	7687	0
Total saddles	8624	6827	14299	4877	88	2294	21523	890

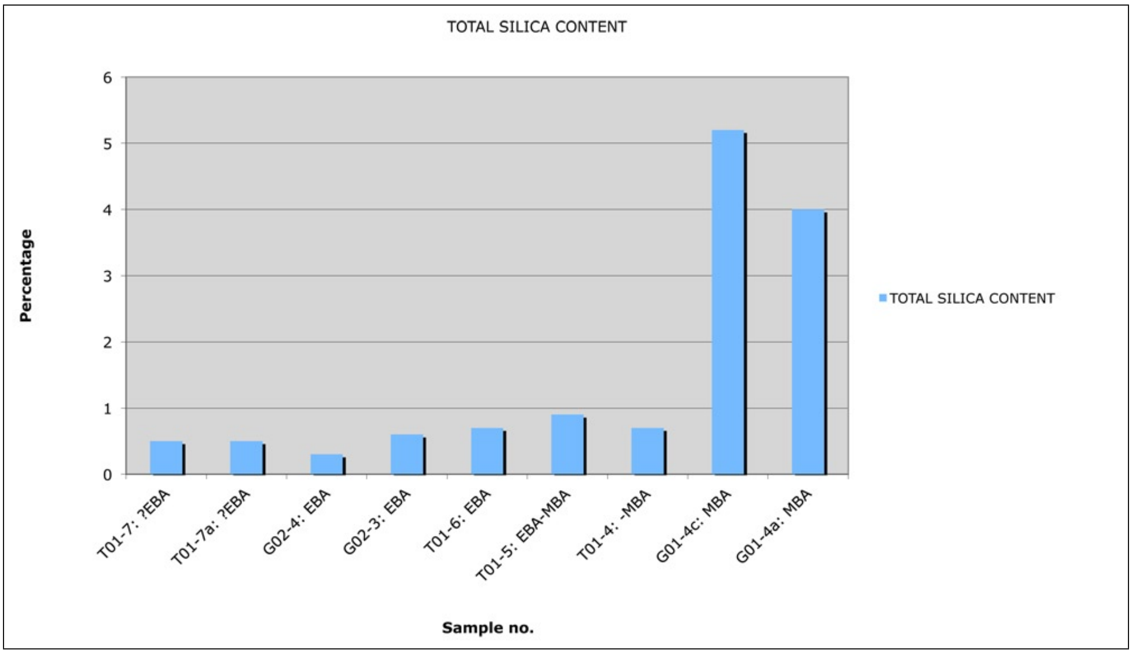
Site: HT onsite samples						
Sample	**SC606-2**	**SC615-1**	**S01-7a**	**S01-7b**	**S01-6**	**S01-6a**
TOTAL SILICA CONTENT	1.5	6.8	2.8	5.3	3	7.3
TOTAL PHYTOLITHS	141623	356662	215851	431903	563324	904553
TOTAL REEDS/PHRAGMITES	0	355	0	0	142	0
TOTAL SEDGES	2706	4264	1689	12909	1566	12985
TOTAL WETLAND PLANTS	2706	4620	1689	12909	1708	12985
TOTAL WHEAT HUSKS	0	0	0	993	0	1623
TOTAL CEREAL HUSKS	601	2843	779	10923	142	14608
TOTAL CEREAL STRAW						
TOTAL CEREALS						
TOTAL WILD GRASS HUSKS	451	711	260	2979	142	0
TOTAL GRASSES AND STRAW	5863	6041	2208	9930	4270	24347
Total wild grasses	5712	5330	1948	6951	4413	19478
TOTAL ?FRUIT	1033	0	0	0	1358.7797	0
TOTAL LEAF	13253	18524	7288	2558	54494	35584
TOTAL BARK/wood	2067	5253	1943	1565	11297	0
TOTAL DICOTS (ADJUSTED)	311565	474855	145755	88485	1158450	583440
TOTAL DICOT SC (ADJUSTED)	282606	442873	145757	58702	1202520.04	560448.974
TOTAL SINGLE CELLS	126290	323259	202602	321685	548947	745486
TOTAL MULTICELLS	15333	33403	13250	110219	14377	159067
Total rondels	24434	29525	47128	54005	101908	140557
Total bilobes	0	5299	972	8610	0	3558
Total saddles	0	9085	8260	38352	4076	19571

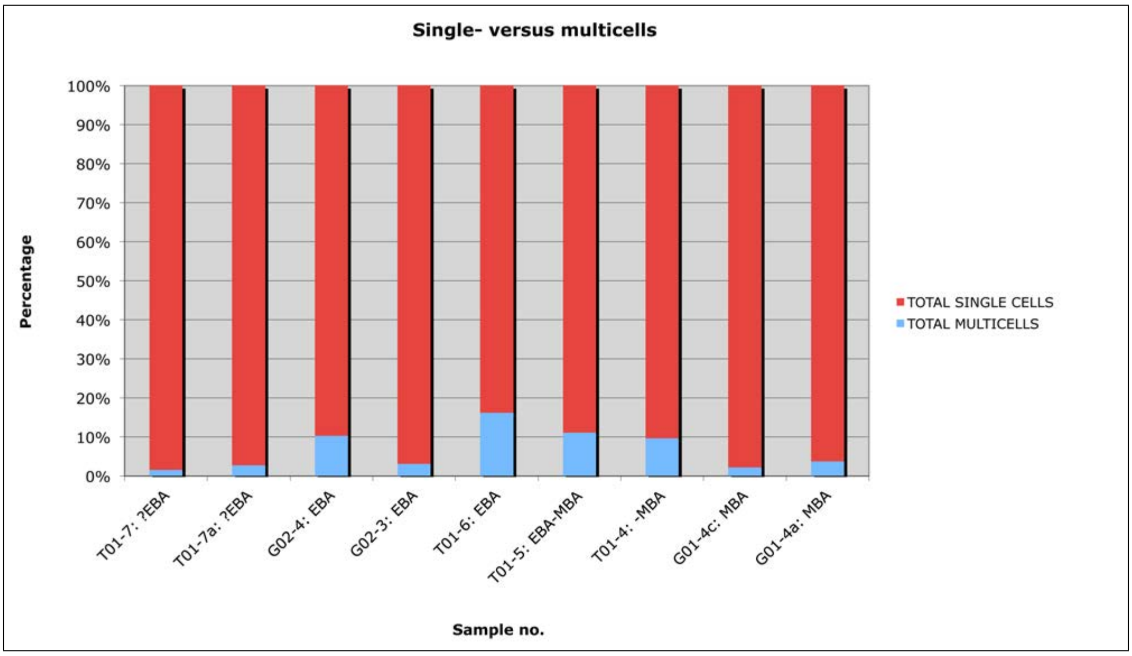
Appendix H

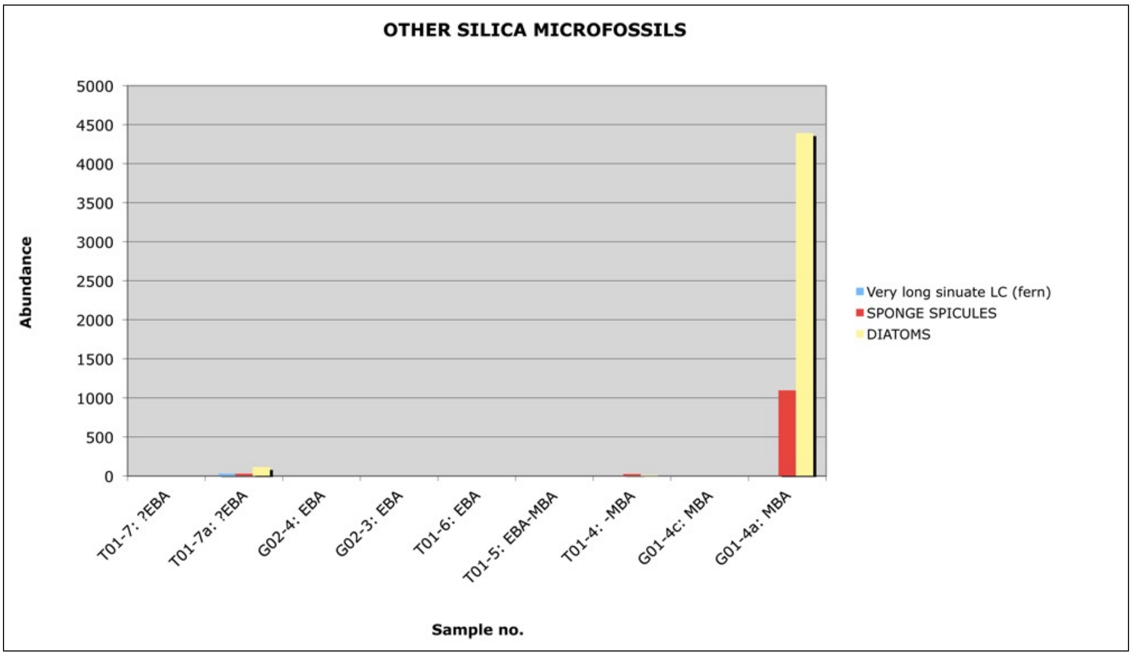
Hirbemerdon Tepe phytolith analysis results: histograms

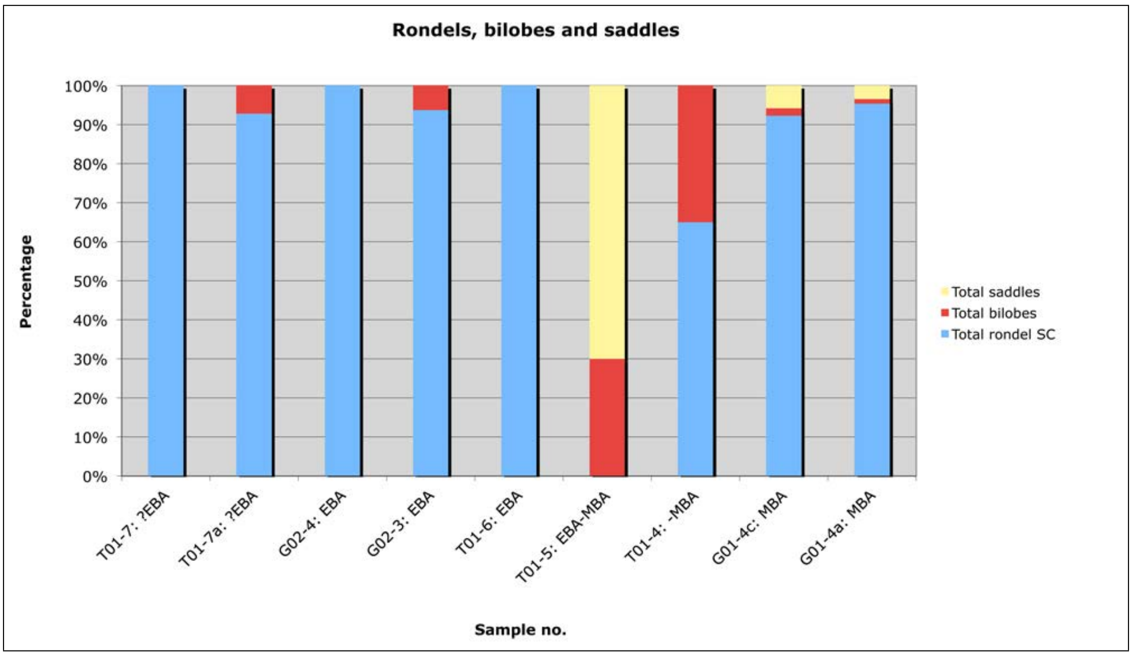
H.1 Offsite histograms

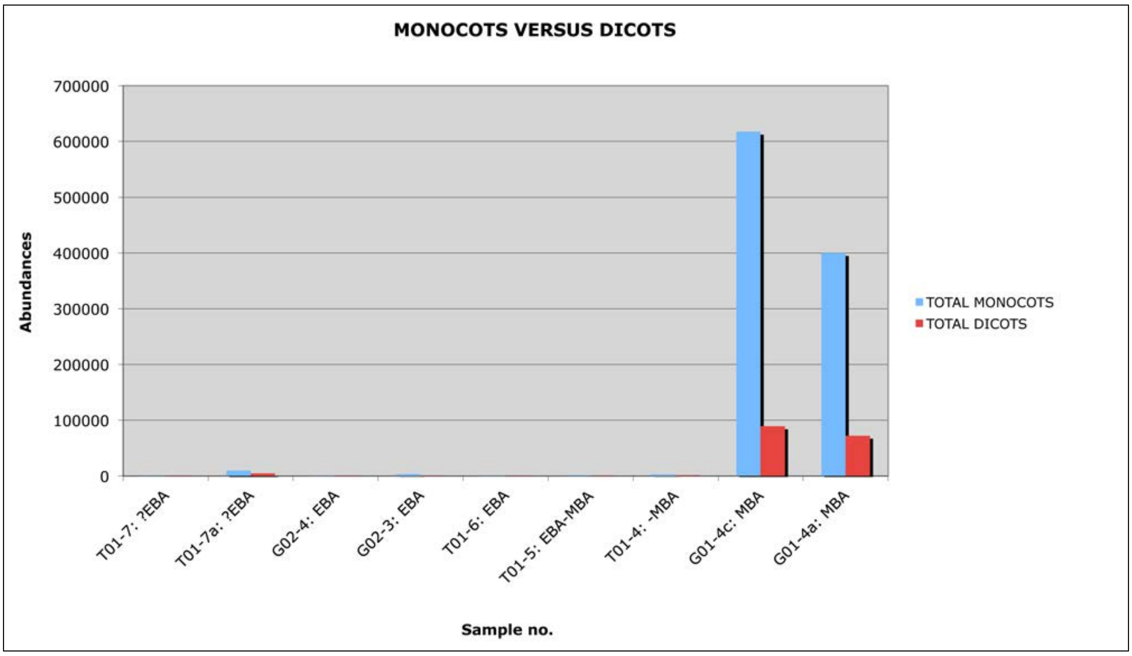


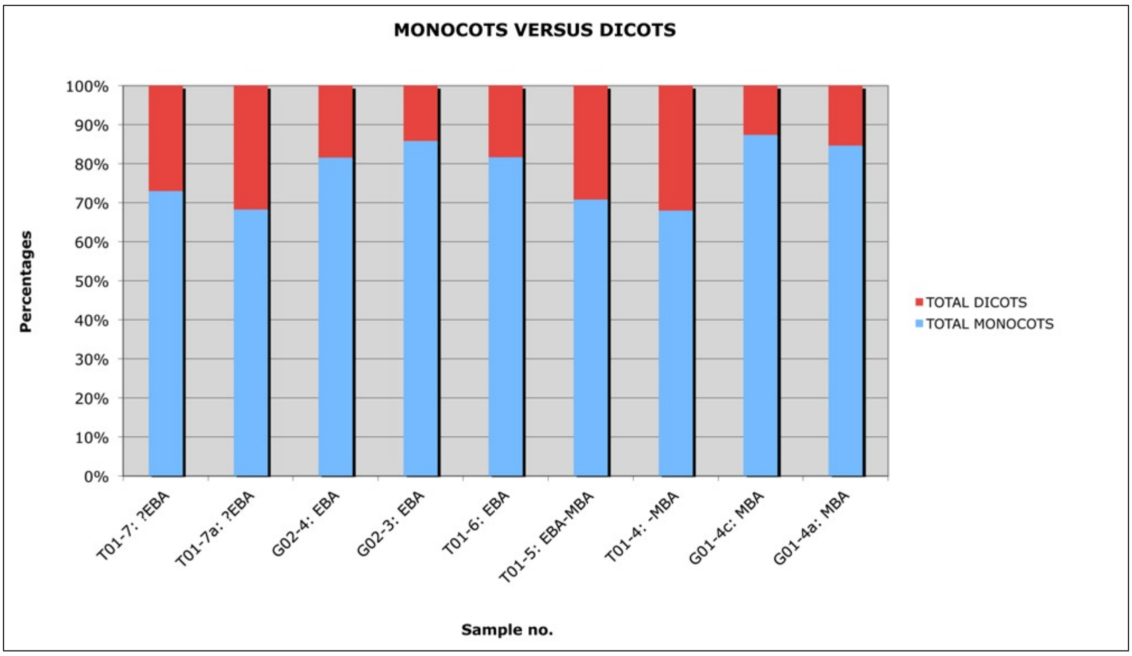

TOTAL SILICA CONTENT
Percentage
6
5
4
3
2
1
0
TOTAL SILICA CONTENT
T01-7: ?EBA
T01-7a: ?EBA
G02-4: EBA
G02-3: EBA
T01-6: EBA
T01-5: EBA-MBA
T01-4: -MBA
G01-4c: MBA
G01-4a: MBA
Sample no.

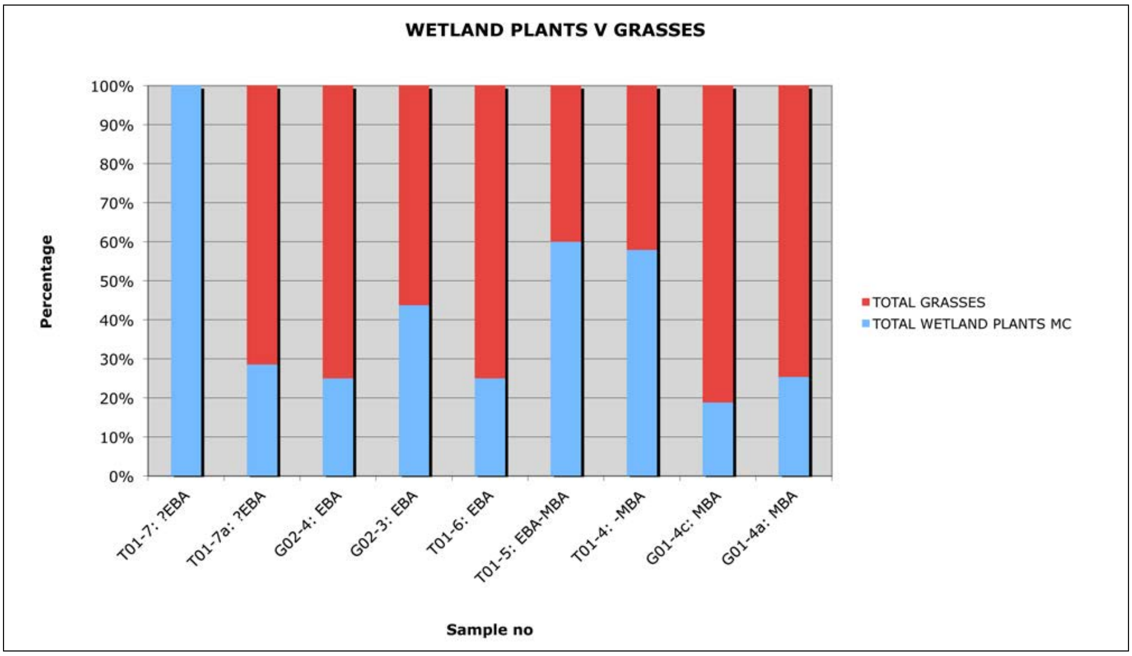

Single- versus multicells
Percentage
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
TOTAL SINGLE CELLS
TOTAL MULTICELLS
T01-7: ?EBA
T01-7a: ?EBA
G02-4: EBA
G02-3: EBA
T01-6: EBA
T01-5: EBA-MBA
T01-4: -MBA
G01-4c: MBA
G01-4a: MBA
Sample no.


OTHER SILICA MICROFOSSILS
Abundance
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
T01-7: ?EBA
T01-7a: ?EBA
G02-4: EBA
G02-3: EBA
T01-6: EBA
T01-5: EBA-MBA
T01-4: -MBA
G01-4c: MBA
G01-4a: MBA
Sample no.
Very long sinuate LC (fern)
SPONGE SPICULES
DIATOMS

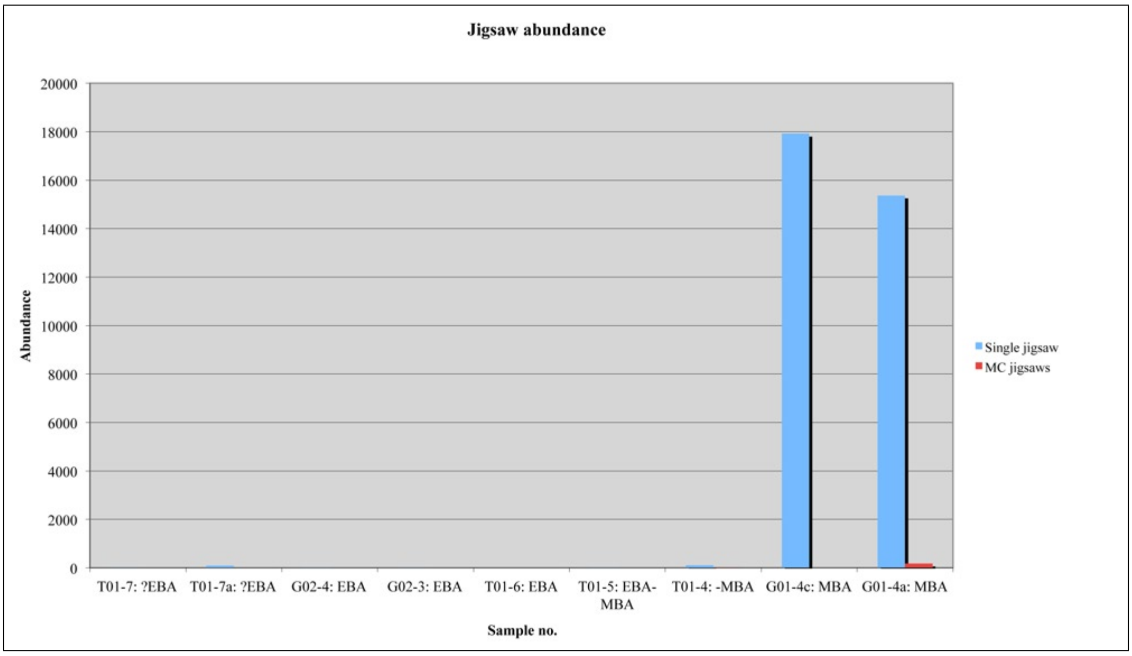

Rondels, bilobes and saddles
Percentage
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
T01-7: ?EBA
T01-7a: ?EBA
G02-4: EBA
G02-3: EBA
T01-6: EBA
T01-5: EBA-MBA
T01-4: -MBA
G01-4c: MBA
G01-4a: MBA
Sample no.
Total saddles
Total bilobes
Total rondel SC


MONOCOTS VERSUS DICOTS
700000
600000
500000
400000
300000
200000
100000
0
Abundances
TOTAL MONOCOTS
TOTAL DICOTS
T01-7: ?EBA
T01-7a: ?EBA
G02-4: EBA
G02-3: EBA
T01-6: EBA
T01-5: EBA-MBA
T01-4: -MBA
G01-4c: MBA
G01-4a: MBA
Sample no.


MONOCOTS VERSUS DICOTS
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percentages
TOTAL DICOTS
TOTAL MONOCOTS
T01-7: ?EBA
T01-7a: ?EBA
G02-4: EBA
G02-3: EBA
T01-6: EBA
T01-5: EBA-MBA
T01-4: -MBA
G01-4c: MBA
G01-4a: MBA
Sample no.

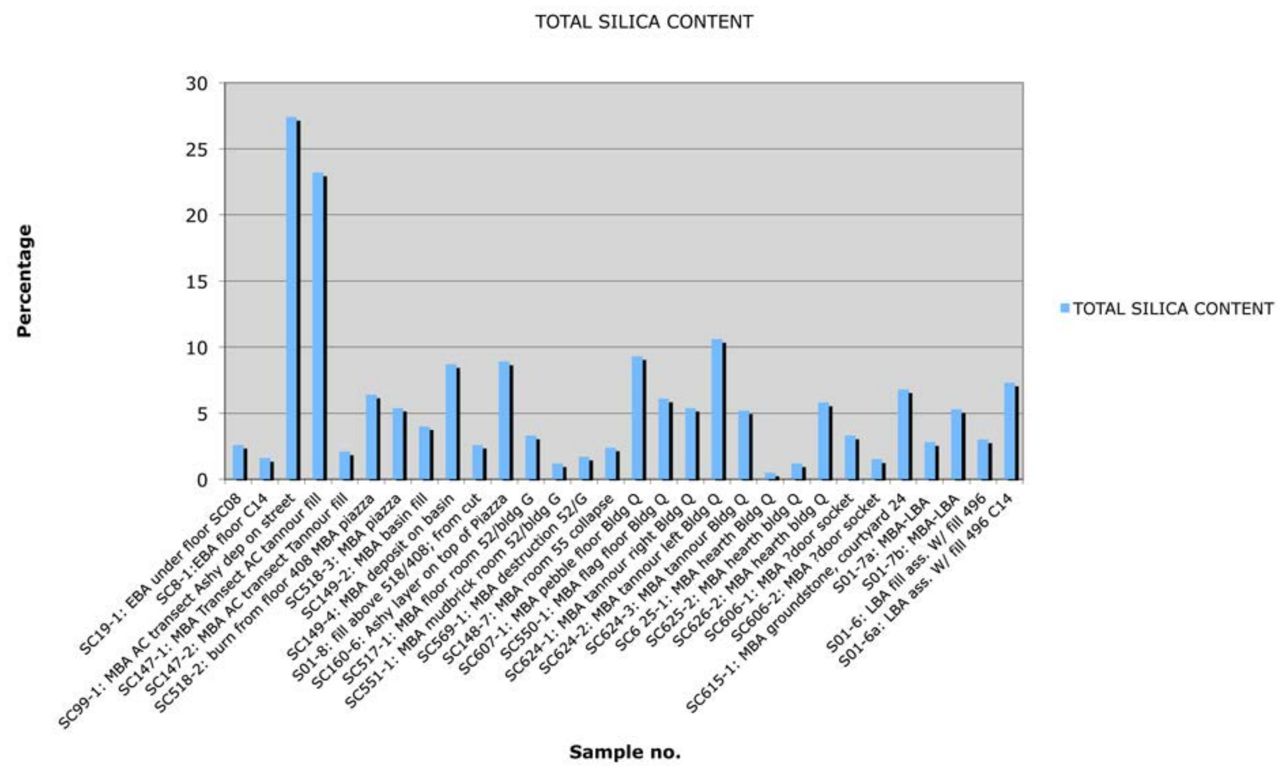


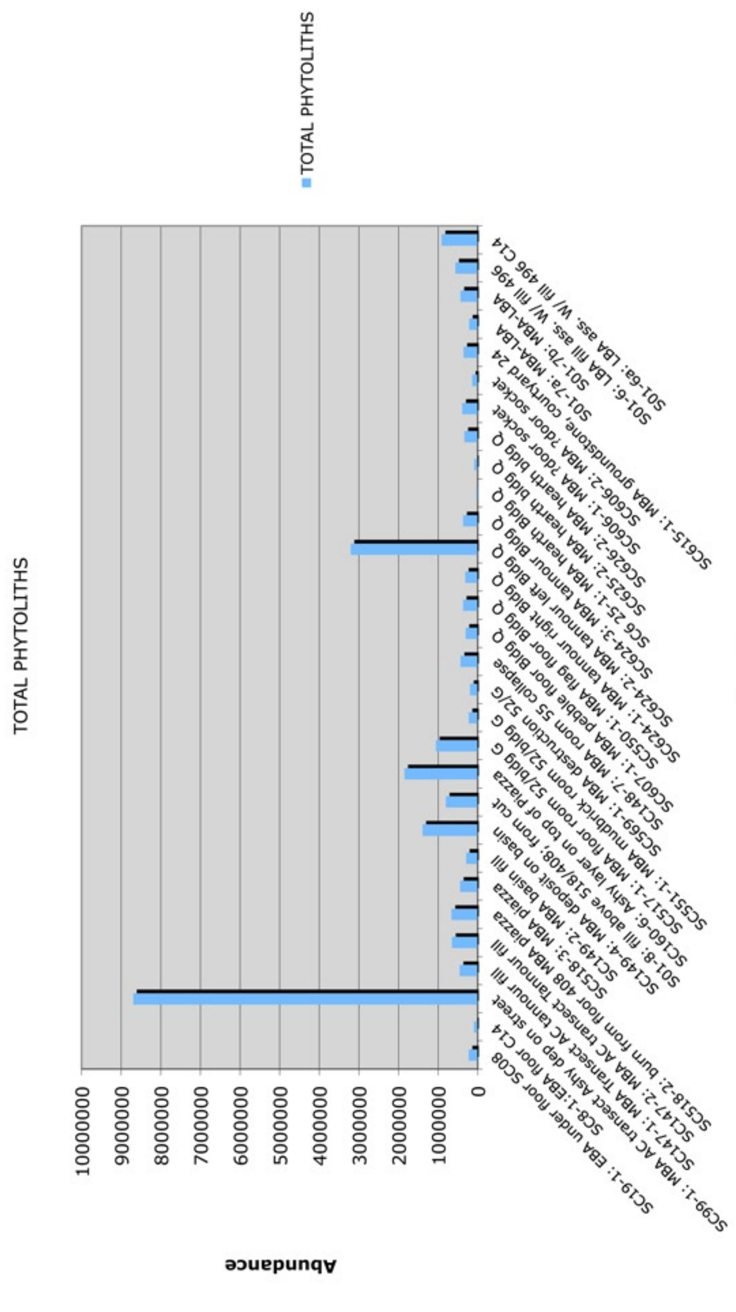
WETLAND PLANTS V GRASSES
Percentage
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
T01-7: ?EBA
T01-7a: ?EBA
G02-4: EBA
G02-3: EBA
T01-6: EBA
T01-5: EBA-MBA
T01-4: -MBA
G01-4c: MBA
G01-4a: MBA
Sample no
TOTAL GRASSES
TOTAL WETLAND PLANTS MC



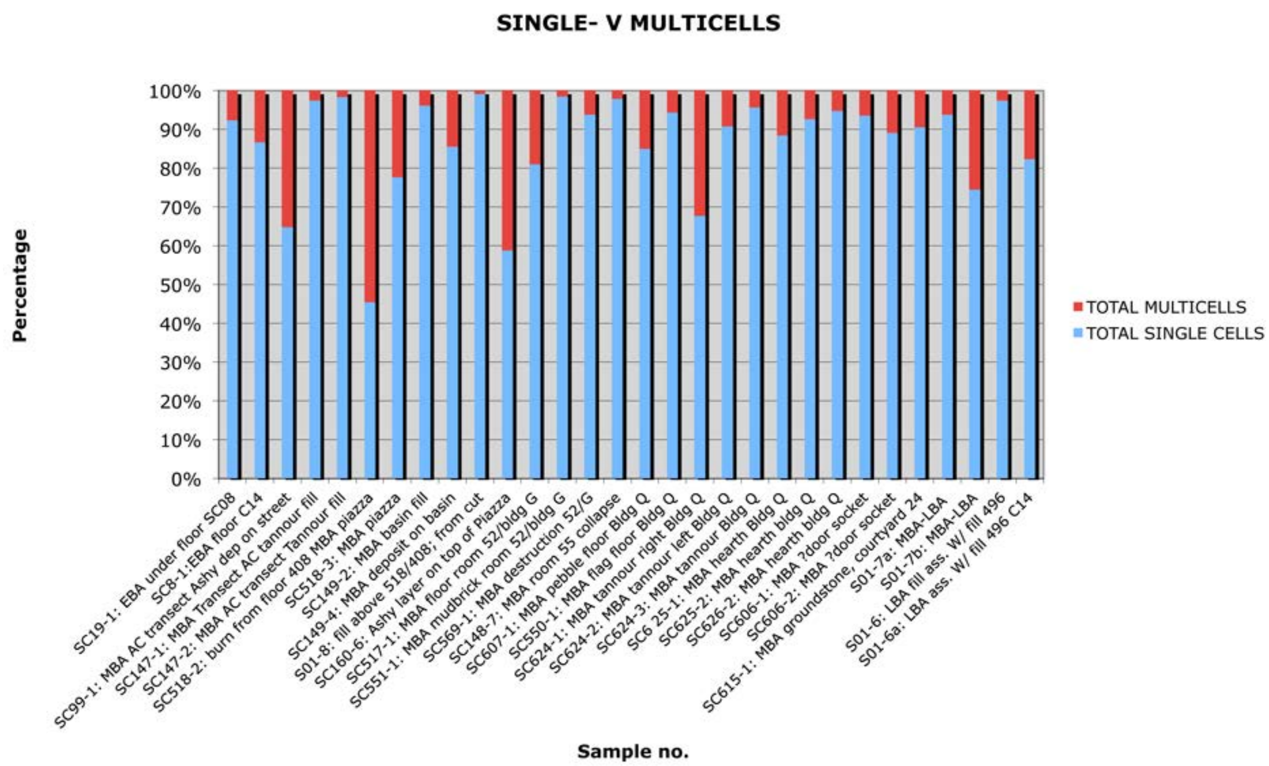
Jigsaw abundance
Abundance
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
T01-7: ?EBA
T01-7a: ?EBA
G02-4: EBA
G02-3: EBA
T01-6: EBA
T01-5: EBA-MBA
T01-4: -MBA
G01-4c: MBA
G01-4a: MBA
Sample no.
Single jigsaw
MC jigsaws

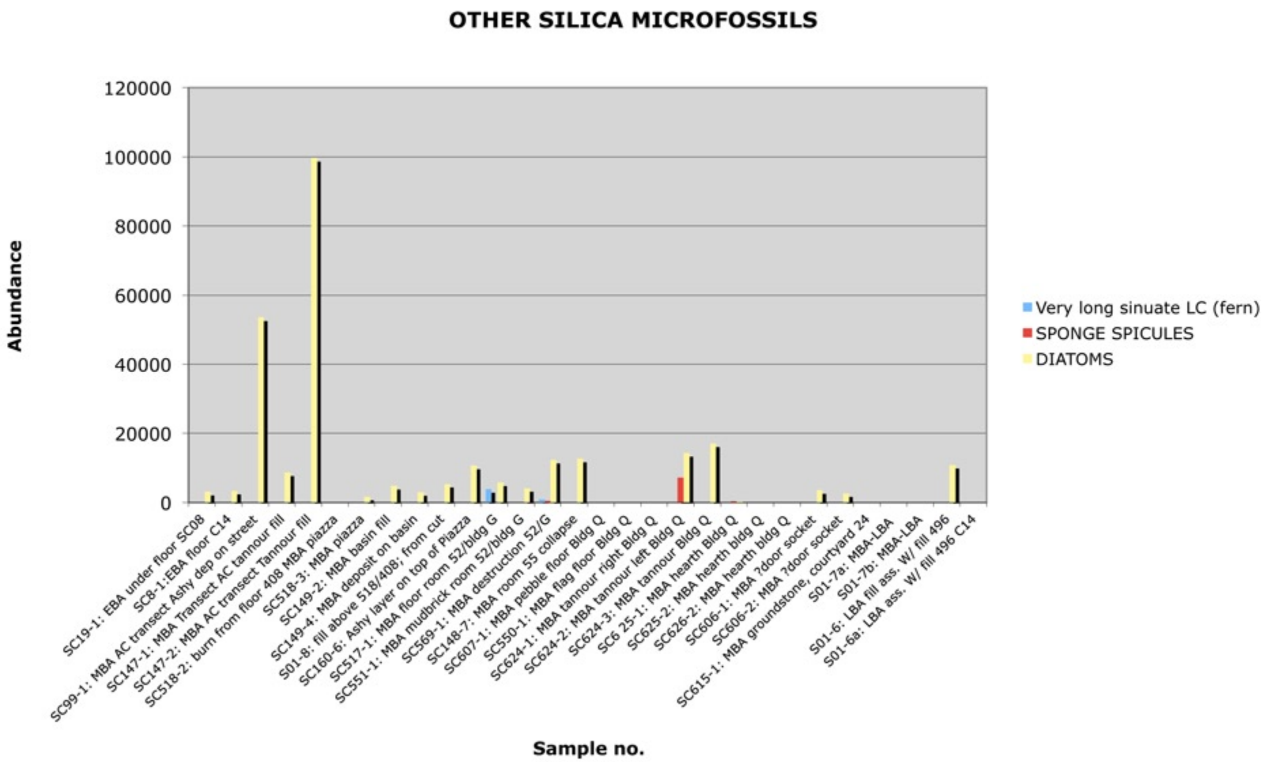
H.2 Onsite histograms


TOTAL SILICA CONTENT
Percentage
30
25
20
15
10
5
0
SC19-1: EBA under floor SC08
SC8-1:EBA floor C14
SC99-1: MBA AC transect Ashy dep on street
SC147-1: MBA Transect AC tannour fill
SC147-2: MBA AC transect Tannour fill
SC518-2: burn from floor 408 MBA piazza
SC518-3: MBA piazza
SC149-2: MBA basin fill
SC149-4: MBA deposit on basin
S01-8: fill above 518/408; from cut
SC160-6: Ashy layer on top of Piazza
SC517-1: MBA floor room 52/bldg G
SC551-1: MBA mudbrick room 52/bldg G
SC569-1: MBA destruction 52/G
SC148-7: MBA room 55 collapse
SC607-1: MBA pebble floor Bldg Q
SC550-1: MBA flag floor Bldg Q
SC624-1: MBA tannour right Bldg Q
SC624-2: MBA tannour left Bldg Q
SC624-3: MBA tannour Bldg Q
SC6 25-1: MBA hearth Bldg Q
SC625-2: MBA hearth bldg Q
SC626-2: MBA hearth bldg Q
SC606-1: MBA ?door socket
SC606-2: MBA ?door socket
SC615-1: MBA groundstone, courtyard 24
S01-7a: MBA-LBA
S01-7b: MBA-LBA
S01-6: LBA fill ass. W/ fill 496
S01-6a: LBA ass. W/ fill 496 C14
Sample no.
TOTAL SILICA CONTENT

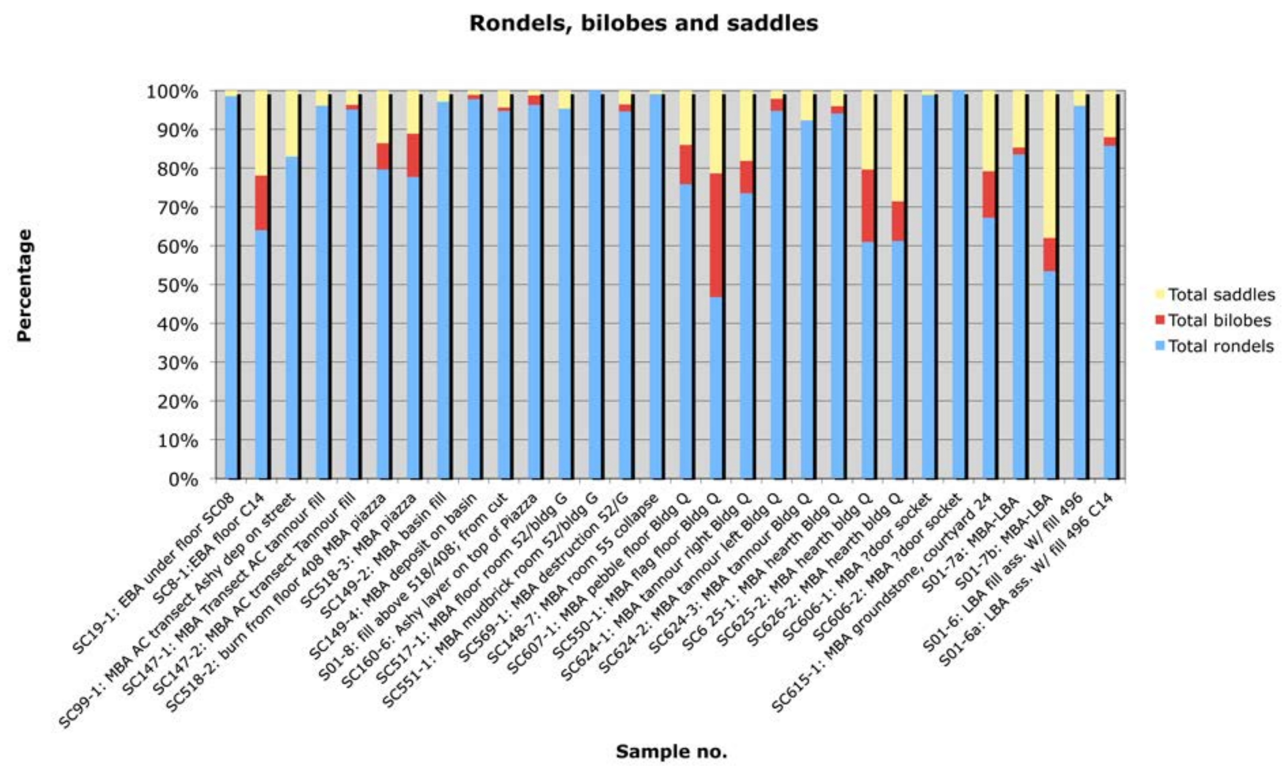


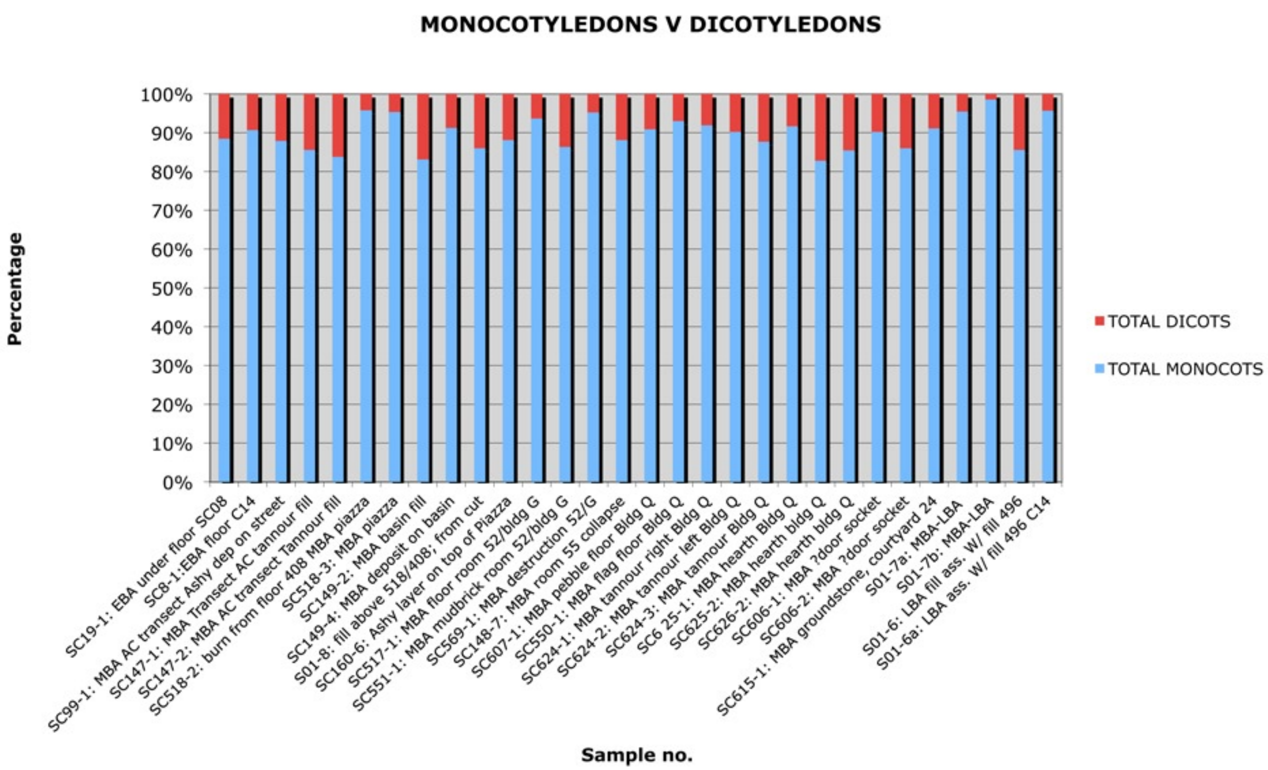
TOTAL PHYTOLITHS
Abundance
0
1000000
2000000
3000000
4000000
5000000
6000000
7000000
8000000
9000000
10000000
Sample no.
TOTAL PHYTOLITHS
SC19-1: EBA under floor SC08
SC8-1:EBA floor C14
SC99-1: MBA AC transect Ashy dep on street
SC147-1: MBA Transect AC tannour fill
SC147-2: MBA AC transect Tannour fill
SC518-2: burn from floor 408 MBA piazza
SC518-3: MBA piazza
SC149-2: MBA piazza
SC149-4: MBA basin fill
S01-8: fill above 518/408; from cut
SC160-6: Ashy deposit on basin
SC517-1: MBA layer on top of piazza
SC551-1: MBA floor room 52/bldg G
SC569-1: MBA mudbrick room 52/bldg G
SC148-7: MBA destruction 52/G
SC607-1: MBA room 55 collapse
SC550-1: MBA pebble floor Bldg Q
SC624-1: MBA flag floor Bldg Q
SC624-2: MBA tannour right Bldg Q
SC624-3: MBA tannour left Bldg Q
SC6 25-1: MBA hearth Bldg Q
SC625-2: MBA hearth bldg Q
SC626-2: MBA ?door socket
SC606-1: MBA ?door socket
SC606-2: MBA groundstone, courtyard 24
SC615-1: MBA groundstone, courtyard 24
S01-7a: MBA-LBA
S01-7b: MBA-LBA
S01-6: LBA fill ass. W/ fill 496
S01-6a: LBA ass. W/ fill 496 C14


SINGLE- V MULTICELLS
Percentage
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
SC19-1: EBA under floor SC08
SC8-1:EBA floor C14
SC99-1: MBA AC transect Ashy dep on street
SC147-1: MBA Transect AC tannour fill
SC147-2: MBA AC transect Tannour fill
SC518-2: burn from floor 408 MBA piazza
SC518-3: MBA piazza
SC149-2: MBA basin fill
SC149-4: MBA deposit on basin
S01-8: fill above 518/408; from cut
SC160-6: Ashy layer on top of Piazza
SC517-1: MBA floor room 52/bldg G
SC551-1: MBA mudbrick room 52/bldg G
SC569-1: MBA destruction 52/G
SC148-7: MBA room 55 collapse
SC607-1: MBA pebble floor Bldg Q
SC550-1: MBA flag floor Bldg Q
SC624-1: MBA tannour right Bldg Q
SC624-2: MBA tannour left Bldg Q
SC624-3: MBA tannour Bldg Q
SC6 25-1: MBA hearth Bldg Q
SC625-2: MBA hearth bldg Q
SC626-2: MBA hearth bldg Q
SC606-1: MBA ?door socket
SC606-2: MBA ?door socket
SC615-1: MBA groundstone, courtyard 24
S01-7a: MBA-LBA
S01-7b: MBA-LBA
S01-6: LBA fill ass. W/ fill 496
S01-6a: LBA ass. W/ fill 496 C14
Sample no.
TOTAL MULTICELLS
TOTAL SINGLE CELLS



OTHER SILICA MICROFOSSILS
Abundance
120000
100000
80000
60000
40000
20000
0
Very long sinuate LC (fern)
SPONGE SPICULES
DIATOMS
SC19-1: EBA under floor SC08
SC8-1:EBA floor C14
SC99-1: MBA AC transect Ashy dep on street
SC147-1: MBA Transect AC tannour fill
SC147-2: MBA AC transect Tannour fill
SC518-2: burn from floor 408 MBA piazza
SC518-3: MBA piazza
SC149-2: MBA basin fill
SC149-4: MBA deposit on basin
S01-8: fill above 518/408; from cut
SC160-6: Ashy layer on top of Piazza
SC517-1: MBA floor room 52/bldg G
SC551-1: MBA mudbrick room 52/bldg G
SC569-1: MBA destruction 52/G
SC148-7: MBA room 55 collapse
SC607-1: MBA pebble floor Bldg Q
SC550-1: MBA flag floor Bldg Q
SC624-1: MBA tannour right Bldg Q
SC624-2: MBA tannour left Bldg Q
SC624-3: MBA tannour Bldg Q
SC6 25-1: MBA hearth Bldg Q
SC625-2: MBA hearth bldg Q
SC626-2: MBA hearth bldg Q
SC606-1: MBA ?door socket
SC606-2: MBA ?door socket
SC615-1: MBA groundstone, courtyard 24
S01-7a: MBA-LBA
S01-7b: MBA-LBA
S01-6: LBA fill ass. W/ fill 496
S01-6a: LBA ass. W/ fill 496 C14
Sample no.


Rondels, bilobes and saddles
Percentage
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
SC19-1: EBA under floor SC08
SC8-1:EBA floor C14
SC99-1: MBA AC transect Ashy dep on street
SC147-1: MBA Transect AC tannour fill
SC147-2: MBA AC transect Tannour fill
SC518-2: burn from floor 408 MBA piazza
SC518-3: MBA piazza
SC149-2: MBA basin fill
SC149-4: MBA deposit on basin
S01-8: fill above 518/408; from cut
SC160-6: Ashy layer on top of Piazza
SC517-1: MBA floor room 52/bldg G
SC551-1: MBA mudbrick room 52/bldg G
SC569-1: MBA destruction 52/G
SC148-7: MBA room 55 collapse
SC607-1: MBA pebble floor Bldg Q
SC550-1: MBA flag floor Bldg Q
SC624-1: MBA tannour right Bldg Q
SC624-2: MBA tannour left Bldg Q
SC624-3: MBA tannour Bldg Q
SC6 25-1: MBA hearth Bldg Q
SC625-2: MBA hearth bldg Q
SC626-2: MBA hearth bldg Q
SC606-1: MBA ?door socket
SC606-2: MBA ?door socket
SC615-1: MBA groundstone, courtyard 24
S01-7a: MBA-LBA
S01-7b: MBA-LBA
S01-6: LBA fill ass. W/ fill 496
S01-6a: LBA ass. W/ fill 496 C14
Sample no.
Total saddles
Total bilobes
Total rondels



MONOCOTYLEDONS V DICOTYLEDONS
Percentage
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
TOTAL DICOTS
TOTAL MONOCOTS
SC19-1: EBA under floor SC08
SC8-1:EBA floor C14
SC99-1: MBA AC transect Ashy dep on street
SC147-1: MBA Transect AC tannour fill
SC147-2: MBA AC transect Tannour fill
SC518-2: burn from floor 408 MBA piazza
SC518-3: MBA piazza
SC149-2: MBA basin fill
SC149-4: MBA deposit on basin
S01-8: fill above 518/408; from cut
SC160-6: Ashy layer on top of Piazza
SC517-1: MBA floor room 52/bidg G
SC551-1: MBA mudbrick room 52/bidg G
SC569-1: MBA destruction 52/G
SC148-7: MBA room 55 collapse
SC607-1: MBA pebble floor Bldg Q
SC550-1: MBA flag floor Bldg Q
SC624-1: MBA tannour right Bldg Q
SC624-2: MBA tannour left Bldg Q
SC624-3: MBA tannour Bldg Q
SC6 25-1: MBA hearth Bldg Q
SC625-2: MBA hearth bldg Q
SC626-2: MBA hearth bldg Q
SC606-1: MBA ?door socket
SC606-2: MBA ?door socket
SC615-1: MBA groundstone, courtyard 24
S01-7a: MBA-LBA
S01-7b: MBA-LBA
S01-6: LBA fill ass. W/ fill 496
S01-6a: LBA ass. W/ fill 496 C14
Sample no.

Appendix I

Bakr Awa and environs phytolith analysis: raw data

I.1 Offsite samples

Site: Bakr Awa / Shahrizor offsite								
Sample	P021	P004	P020	P003	P014	P013	P012	P002
	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm
MONOCOTS								
SINGLE CELLS								
Psilate long cell	14	9	9	7	6	7	7	10
Sinuate long cell	0	0	0	1	1	0	0	1
Dentritic long cell	2	0	0	2	0	0	1	1
Trapezoid sinuate/crenate	8	4	0	4	0	0	3	2
Papillae	8	0	2	0	0	0	0	0
?Emmer papillae (stubble)	0	0	0	0	0	3	0	0
Keystone bulliform	6	1	0	12	3	0	10	5
Bilobe Chloridoid (C4)	0	0	0	0	0	0	0	0
Bilobe Panicoid (Most C4)	0	0	0	0	0	0	0	0
Bilobe Aruninoid (Most C3)	0	0	0	0	0	0	0	0
Bilobe indet	2	0	2	1	0	0	0	1
Saddle Chloridoid	0	0	0	0	0	0	0	0
Saddle Aruninoid	0	0	0	0	0	0	0	0
Saddle indet	0	0	0	0	0	0	0	0
Polylobate	0	0	0	0	0	0	0	1
Quadralobe	0	0	0	0	0	0	0	0
Rondel	2	1	0	4	1	2	0	13
Flat tower	2	0	0	0	0	0	0	0
Horned tower	0	1	0	0	0	0	0	0
Elliptical psilate	0	0	3	0	0	1	0	1
rectangular psilate (small)	8	0	5	0	0	3	1	5
Grass SC indet	0	0	0	0	1	0	0	0
Echinate long cell	2	0	0	0	0	0	0	0
Crenate LC	0	0	0	0	0	0	0	0
Psilate long cell rod	4	0	0	4	2	3	4	5

Site: Bakr Awa / Shahrizor offsite							
Sample	P026	P025	P010	P024	P009	P019	P011
	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm
MONOCOTS							
SINGLE CELLS							
Psilate long cell	58	276	16	11	38	16	5
Sinuate long cell	4	31	0	0	2	1	0
Dentritic long cell	3	41	0	2	0	0	0
Trapezoid sinuate/crenate	6	10	1	3	5	3	1
Papillae	4	0	0	0	0	0	0
?Emmer papillae (stubble)	0	0	0	0	0	0	0
Keystone bulliform	17	138	12	2	58	8	11
Bilobe Chloridoid (C4)	0	0	0	0	0	0	0
Bilobe Panicoid (Most C4)	0	0	0	0	0	0	0
Bilobe Aruninoid (Most C3)	0	0	0	0	0	0	0
Bilobe indet	0	0	0	1	0	0	0
Saddle Chloridoid	1	0	0	0	0	0	0
Saddle Aruninoid	0	0	0	0	0	0	0
Saddle indet	0	0	0	0	2	0	1
Polylobate	1	5	2	1	0	0	1
Quadralobe	0	0	0	0	0	0	0
Rondel	46	67	6	14	46	1	3
Flat tower	0	5	0	1	0	0	0
Horned tower	0	0	0	0	0	0	0
Elliptical psilate	6	0	3	3	9	1	3
rectangular psilate (small)	12	31	7	12	13	3	3
Grass SC indet	0	0	0	0	0	0	0
Echinate long cell	10	10	1	1	2	1	0
Crenate LC	0	0	0	0	0	0	0
Psilate long cell rod	7	10	1	0	2	0	3

Site: Bakr Awa / Shahrizor offsite			
Sample	**P018**	**P001**	**P023**
	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm
MONOCOTS			
SINGLE CELLS			
Psilate long cell	5	11	1085209
Sinuate long cell	1	1	234640
Dentritic long cell	1	0	58660
Trapezoid sinuate/crenate	0	3	87990
Papillae	0	1	58660
?Emmer papillae (stubble)	0	0	0
Keystone bulliform	3	6	615929
Bilobe Chloridoid (C4)	0	0	0
Bilobe Panicoid (Most C4)	0	0	0
Bilobe Aruninoid (Most C3)	0	0	0
Bilobe indet	1	0	0
Saddle Chloridoid	0	0	0
Saddle Aruninoid	0	0	0
Saddle indet	0	0	29330
Polylobate	0	0	87990
Quadralobe	0	0	0
Rondel	8	3	821239
Flat tower	0	0	87990
Horned tower	0	0	29330
Elliptical psilate	1	1	0
rectangular psilate (small)	2	2	117320
Grass SC indet	0	0	0
Echinate long cell	1	2	205310
Crenate LC	0	0	0
Psilate long cell rod	2	3	117320

Site: Bakr Awa / Shahrizor offsite								
Sample	**P021**	**P004**	**P020**	**P003**	**P014**	**P013**	**P012**	**P002**
	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm
SINGLE CELLS								
Echinate long cell rod	0	0	0	1	0	1	0	2
Cylindric psilate long cell	0	0	0	0	1	0	0	0
Psilate assymetrical LC	6	3	2	1	3	1	3	5
Echinate assymetrical LC	0	0	2	1	1	1	0	0
Psilate LC w/projections on 1 side	0	0	0	0	0	0	0	0
Prickle hairs	14	0	9	1	0	2	3	2
Tricomes	2	0	5	2	0	1	0	4
Hairs	8	0	0	1	0	0	0	0
Bulliforms	14	1	9	18	14	25	31	22
?Bulliforms (echinate semi-sphere)	0	0	2	0	0	0	1	1
Stomata	0	0	0	0	0	0	0	0
Tetracytic stomata (?Scirpus)	0	0	0	0	0	0	0	0
Sedge cones	38	9	14	6	10	10	39	23
Globular echinate cf date palm	0	0	0	0	0	0	0	0
Globular spinulose cf Doum palm	0	0	0	0	0	0	0	0
Trapezoid	2	0	2	1	0	2	0	1
Indet monocot SC	12	6	5	0	6	11	17	5
TOTAL MONOCOT SC	154	36	71	68	49	71	120	109
MULTICELLS								
Silica skeleton psilate LC	0	1	3	1	1	1	0	0
Silica skeleton sinuate LC	0	0	0	0	0	0	0	0
Silica skeleton echinate LC	0	0	0	0	0	0	0	0
Indet monocot leaf/stem	0	0	0	1	1	0	0	0
Silica skelton LC and stomata	0	0	0	0	0	0	0	0
leaf/stem with grass stomata	0	0	0	0	0	0	0	0
leaf/stem with rondels	0	0	0	0	0	0	0	0

Site: Bakr Awa / Shahrizor offsite							
Sample	P026	P025	P010	P024	P009	P019	P011
	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm
SINGLE CELLS							
Echinate long cell rod	0	0	0	0	0	0	1
Cylindric psilate long cell	0	5	0	0	0	1	0
Psilate assymetrical LC	17	10	5	3	13	3	9
Echinate assymetrical LC	1	0	0	0	0	3	0
Psilate LC w/projections on 1 side	0	0	0	0	0	0	0
Prickle hairs	20	67	3	31	5	3	1
Tricomes	12	72	5	13	13	0	2
Hairs	0	0	0	5	0	0	0
Bulliforms	33	225	27	17	115	14	38
?Bulliforms (echinate semi-sphere)	0	10	0	2	0	0	0
Stomata	0	0	0	0	0	0	0
Tetracytic stomata (?Scirpus)	0	0	0	0	0	0	0
Sedge cones	78	379	37	80	157	30	21
Globular echinate cf date palm	0	5	0	0	0	0	0
Globular spinulose cf Doum palm	0	0	0	0	0	0	0
Trapezoid	16	20	2	1	11	1	1
Indet monocot SC	38	61	16	12	17	12	19
TOTAL MONOCOT SC	390	1478	143	215	504	101	125
MULTICELLS							
Silica skeleton psilate LC	7	16	0	2	0	1	0
Silica skeleton sinuate LC	0	1	0	0	0	0	0
Silica skeleton echinate LC	0	0	0	1	0	0	0
Indet monocot leaf/stem	6	8	0	10	0	0	0
Silica skelton LC and stomata	0	0	0	0	0	0	0
leaf/stem with grass stomata	0	0	0	0	0	1	0
leaf/stem with rondels	0	0	0	1	0	0	0

Site: Bakr Awa / Shahrizor offsite			
Sample	**P018**	**P001**	**P023**
	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm
SINGLE CELLS			
Echinate long cell rod	1	0	58660
Cylindric psilate long cell	0	0	58660
Psilate assymetrical LC	1	4	322630
Echinate assymetrical LC	0	0	146650
Psilate LC w/projections on 1 side	0	0	29330
Prickle hairs	5	0	205310
Tricomes	3	2	469279
Hairs	1	0	29330
Bulliforms	10	7	1202528
?Bulliforms (echinate semi-sphere)	0	1	29330
Stomata	0	0	0
Tetracytic stomata (?Scirpus)	0	0	0
Sedge cones	15	20	1818458
Globular echinate cf date palm	0	0	0
Globular spinulose cf Doum palm	0	0	0
Trapezoid	1	0	146650
Indet monocot SC	10	2	909229
TOTAL MONOCOT SC	72	71	9062958
MULTICELLS			
Silica skeleton psilate LC	2	1	14366
Silica skeleton sinuate LC	0	0	2394
Silica skeleton echinate LC	0	0	0
Indet monocot leaf/stem	0	0	0
Silica skelton LC and stomata	0	0	0
leaf/stem with grass stomata	0	0	0
leaf/stem with rondels	0	0	1197

Site: Bakr Awa / Shahrizor offsite								
Sample	P021	P004	P020	P003	P014	P013	P012	P002
	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm
MULTICELLS								
leaf/stem with bilobes indet	0	0	0	0	0	0	0	0
leaf/stem with chloridoid bilobes	0	0	0	0	0	0	0	0
leaf/stem with panicoid bilobes	0	0	0	0	0	0	0	0
leaf/stem with arunidoid bilobes	0	0	0	0	0	0	0	0
Phragmite leaf	0	0	0	0	0	0	0	0
phragmite stem	0	0	0	0	0	0	0	0
leaf/stem with saddles indet	0	0	0	0	0	0	0	0
leaf/stem with choridoid saddles	0	0	0	0	0	0	0	0
leaf/stem with arunidoid saddles	0	0	0	0	0	0	0	0
leaf/stem with quadralobes	0	0	0	0	0	0	0	0
leaf/stem with bulliforms	0	0	0	1	1	0	1	0
leaf/stem with crenates	0	0	0	0	0	0	0	0
square cell leaf/stem	0	0	0	0	0	0	0	0
multiple bulliforms	0	0	0	0	1	0	0	0
Stem with hair	0	0	0	0	0	0	0	0
Assymetrical LCs	0	0	0	2	2	1	0	1
Cylindrical (rods) and LCs	0	0	0	1	1	1	3	0
Sedge cones	2	3	0	0	0	0	1	0
Visible mesophyll	0	0	0	0	0	0	0	0
Indet husk	0	0	0	0	1	0	0	0
Wheat husk indet	0	0	0	0	0	0	0	0
Emmer wheat	0	0	0	0	0	0	0	0
Durum wheat	0	0	0	0	0	0	0	0
Einkorn wheat	0	0	0	0	0	0	0	0
Bread wheat	0	0	0	0	0	0	0	0
Barley husk	0	0	0	0	0	0	0	0

Site: Bakr Awa / Shahrizor offsite							
Sample	P026	P025	P010	P024	P009	P019	P011
	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm
MULTICELLS							
leaf/stem with bilobes indet	0	0	0	0	0	0	0
leaf/stem with chloridoid bilobes	0	0	0	0	0	0	0
leaf/stem with panicoid bilobes	0	0	0	0	0	0	0
leaf/stem with arunidoid bilobes	0	0	0	0	0	0	0
Phragmite leaf	1	1	0	0	0	0	0
phragmite stem	0	0	0	0	0	0	0
leaf/stem with saddles indet	0	0	0	0	0	0	0
leaf/stem with choridoid saddles	0	0	0	0	0	0	0
leaf/stem with arunidoid saddles	0	0	0	0	0	0	0
leaf/stem with quadralobes	0	0	0	0	0	0	0
leaf/stem with bulliforms	0	1	0	0	0	0	0
leaf/stem with crenates	0	0	0	0	0	0	0
square cell leaf/stem	0	0	0	0	0	0	0
multiple bulliforms	0	4	1	1	1	0	0
Stem with hair	0	3	0	1	0	1	0
Assymetrical LCs	0	0	0	0	0	0	0
Cylindrical (rods) and LCs	3	7	0	0	0	0	0
Sedge cones	3	6	0	8	1	0	1
Visible mesophyll	0	0	0	0	0	0	0
Indet husk	0	1	0	0	0	0	0
Wheat husk indet	0	1	0	0	0	0	0
Emmer wheat	0	0	0	0	0	0	0
Durum wheat	0	0	0	0	0	0	0
Einkorn wheat	0	0	0	0	0	0	0
Bread wheat	0	0	0	0	0	0	0
Barley husk	0	0	0	0	0	0	0

Site: Bakr Awa / Shahrizor offsite			
Sample	**P018**	**P001**	**P023**
	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm
MULTICELLS			
leaf/stem with bilobes indet	0	0	0
leaf/stem with chloridoid bilobes	0	0	0
leaf/stem with panicoid bilobes	0	0	0
leaf/stem with arunidoid bilobes	0	0	0
Phragmite leaf	0	2	1197
phragmite stem	0	0	0
leaf/stem with saddles indet	0	0	0
leaf/stem with choridoid saddles	0	0	0
leaf/stem with arunidoid saddles	0	0	0
leaf/stem with quadralobes	0	0	0
leaf/stem with bulliforms	0	0	0
leaf/stem with crenates	0	0	0
square cell leaf/stem	0	0	0
multiple bulliforms	0	0	1197
Stem with hair	1	0	0
Assymetrical LCs	0	1	4789
Cylindrical (rods) and LCs	0	0	0
Sedge cones	1	1	5986
Visible mesophyll	0	0	0
Indet husk	0	0	0
Wheat husk indet	0	0	0
Emmer wheat	0	0	0
Durum wheat	0	0	0
Einkorn wheat	0	0	0
Bread wheat	0	0	0
Barley husk	0	0	0

Site: Bakr Awa / Shahrizor offsite								
Sample	P021	P004	P020	P003	P014	P013	P012	P002
	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm
MULTICELLS								
Cereal straw	0	0	0	0	0	0	0	0
Awn	0	0	0	0	0	0	0	0
Papillae aggragation (distal)	0	0	0	0	0	0	0	0
Setaria	0	0	0	0	0	0	0	0
Aegilops (goat grass)	0	0	0	0	0	0	0	0
Bromus	0	0	0	0	0	0	0	0
Avena (oat grass)	0	0	0	0	0	0	0	0
Lolium (rye grass)	0	0	0	0	0	0	0	0
Scirpus type (tetracytic stomata)	0	0	0	0	0	0	0	0
Wild grass husk	0	0	0	0	0	0	0	0
Stem (indet grass)	0	0	0	0	0	0	0	0
panicoid bilobes	0	0	0	0	0	0	0	0
Indet MC	0	0	0	0	1	0	0	0
TOTAL MONOCOT MC	2	4	3	6	10	3	5	1
TOTAL MONOCOTS	156	40	74	74	58	74	126	110
DICOTS								
SINGLE CELLS								
Globular psilate	10	0	7	1	0	0	1	0
Globular multifaceted	0	0	0	0	0	0	0	0
Globular verrucate	16	9	2	4	6	7	21	5
Dicot elongate (oblong)	0	21	0	2	1	3	5	3
Tracheid	2	0	2	0	0	0	1	0
Blocks	2	4	0	2	0	0	3	1
Platey	0	0	0	0	0	0	0	0
Sheet - clear (platelet)	18	33	10	11	1	4	8	7
Sheet - scrobiculate	24	3	10	7	3	3	7	17

Site: Bakr Awa / Shahrizor offsite							
Sample	P026	P025	P010	P024	P009	P019	P011
	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm
MULTICELLS							
Cereal straw	0	0	0	0	0	0	0
Awn	0	0	0	4	0	0	0
Papillae aggragation (distal)	0	0	0	0	0	0	0
Setaria	0	0	0	0	0	0	0
Aegilops (goat grass)	0	0	0	0	0	0	0
Bromus	1	0	0	0	0	0	0
Avena (oat grass)	0	0	0	0	0	0	0
Lolium (rye grass)	0	0	0	0	0	0	0
Scirpus type (tetracytic stomata)	0	0	0	0	0	0	0
Wild grass husk	1	1	0	4	0	0	0
Stem (indet grass)	0	0	0	1	0	0	0
panicoid bilobes	0	0	0	0	0	0	0
Indet MC	3	8	0	8	0	0	1
TOTAL MONOCOT MC	25	58	1	41	2	3	2
TOTAL MONOCOTS	415	1536	143	256	506	104	127
DICOTS							
SINGLE CELLS							
Globular psilate	6	5	2	12	0	0	3
Globular multifaceted	0	0	0	0	0	0	0
Globular verrucate	26	46	29	16	47	1	10
Dicot elongate (oblong)	1	0	0	2	6	0	0
Tracheid	0	5	0	2	0	0	0
Blocks	0	10	2	0	2	3	0
Platey	0	0	0	0	3	0	0
Sheet - clear (platelet)	25	102	6	18	3	9	5
Sheet - scrobiculate	16	77	14	13	17	1	21

Site: Bakr Awa / Shahrizor offsite			
Sample	**P018**	**P001**	**P023**
	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm
MULTICELLS			
Cereal straw	0	0	0
Awn	0	0	0
Papillae aggragation (distal)	0	0	0
Setaria	0	0	0
Aegilops (goat grass)	0	0	0
Bromus	0	0	1197
Avena (oat grass)	0	0	0
Lolium (rye grass)	0	0	0
Scirpus type (tetracytic stomata)	0	0	0
Wild grass husk	0	0	5986
Stem (indet grass)	0	0	2394
panicoid bilobes	0	0	0
Indet MC	0	0	3591
TOTAL MONOCOT MC	4	5	44294
TOTAL MONOCOTS	76	76	9107252
DICOTS			
SINGLE CELLS			
Globular psilate	1	1	117320
Globular multifaceted	0	0	0
Globular verrucate	4	3	175980
Dicot elongate (oblong)	0	4	29330
Tracheid	0	0	0
Blocks	1	0	29330
Platey	0	0	0
Sheet - clear (platelet)	4	6	381289
Sheet - scrobiculate	4	12	87990

Site: Bakr Awa / Shahrizor offsite								
Sample	P021	P004	P020	P003	P014	P013	P012	P002
	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm
SINGLE CELLS								
Sheet - spotted	0	0	0	0	0	0	0	0
Sheet - striated	0	0	0	0	0	0	0	0
Tricomes (cf Metcalfe)	0	0	0	0	0	0	0	0
Opaque platelets (Bozarth)	0	0	0	0	0	0	0	0
solid opaque platelets	0	0	0	0	0	0	0	0
Single polyhedral (Bozarth)	34	0	26	5	2	4	8	2
Decorated polyhedral (4-8 sides)	0	0	0	0	0	0	0	0
Single jigsaw	0	0	0	0	0	0	0	0
Verrucate	4	0	0	0	0	0	0	0
Stipa type rondel	0	0	0	0	0	0	0	0
Scalloped (round)	0	0	0	0	0	0	0	0
Scalloped (see Bozarth)	0	0	2	1	0	0	0	1
Pinaceae tracheids	0	0	0	0	0	0	0	0
Irregular echinate LC	0	0	0	0	0	0	0	0
Conifer blocky polyhedral (>8 side)	0	0	0	0	0	0	0	0
Sclereid	14	14	3	11	2	0	4	3
Astroscelerid	0	1	0	0	0	0	0	0
large sphere (holes)	0	0	0	0	1	0	1	0
Stellate	0	0	2	0	1	0	0	1
Indet dicot SC	2	7	0	4	0	1	0	4
TOTAL DICOT SC	126	93	64	50	18	23	59	43
MULTICELLS								
Multi LCs	0	1	0	0	0	0	0	0
Multiple jigsaws	0	0	0	0	0	0	0	0
polyhedral (Bozarth)	2	0	0	0	0	0	0	0
decorated polyhedral (4-8 sides)	0	0	0	0	0	0	0	0

Site: Bakr Awa / Shahrizor offsite							
Sample	**P026**	**P025**	**P010**	**P024**	**P009**	**P019**	**P011**
	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm
SINGLE CELLS							
Sheet - spotted	9	0	0	3	0	0	1
Sheet - striated	0	5	0	0	0	0	0
Tricomes (cf Metcalfe)	0	0	0	0	0	0	0
Opaque platelets (Bozarth)	0	0	0	0	0	0	0
solid opaque platelets	0	0	0	0	0	0	0
Single polyhedral (Bozarth)	61	184	11	34	24	0	13
Decorated polyhedral (4-8 sides)	4	10	0	5	0	35	0
Single jigsaw	16	72	1	2	0	0	0
Verrucate	3	15	0	0	8	0	0
Stipa type rondel	0	0	0	0	0	0	0
Scalloped (round)	3	10	0	1	0	0	0
Scalloped (see Bozarth)	4	0	0	1	0	0	0
Pinaceae tracheids	0	0	0	0	0	0	0
Irregular echinate LC	0	0	0	0	0	0	0
Conifer blocky polyhedral (>8 side)	0	0	0	0	0	0	0
Sclereid	0	0	6	7	11	5	13
Astroscelerid	0	0	0	0	0	0	0
large sphere (holes)	0	0	0	0	0	0	1
Stellate	1	0	0	1	0	0	2
Indet dicot SC	22	31	0	13	3	7	1
TOTAL DICOT SC	197	572	70	130	124	61	71
MULTICELLS							
Multi LCs	0	0	0	0	0	0	0
Multiple jigsaws	0	0	0	0	0	0	0
polyhedral (Bozarth)	0	1	0	4	0	0	0
decorated polyhedral (4-8 sides)	0	0	0	0	0	0	0

Site: Bakr Awa / Shahrizor offsite			
Sample	**P018**	**P001**	**P023**
	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm
SINGLE CELLS			
Sheet - spotted	0	1	0
Sheet - striated	0	0	0
Tricomes (cf Metcalfe)	0	0	0
Opaque platelets (Bozarth)	0	0	0
solid opaque platelets	0	0	0
Single polyhedral (Bozarth)	8	11	850569
Decorated polyhedral (4-8 sides)	0	0	29330
Single jigsaw	0	0	263970
Verrucate	1	0	87990
Stipa type rondel	0	0	29330
Scalloped (round)	0	0	0
Scalloped (see Bozarth)	1	1	146650
Pinaceae tracheids	0	0	0
Irregular echinate LC	0	0	0
Conifer blocky polyhedral (>8 side)	0	0	0
Sclereid	5	15	117320
Astroscelerid	0	1	29330
large sphere (holes)	0	0	0
Stellate	1	0	0
Indet dicot SC	0	2	322630
TOTAL DICOT SC	30	57	2698356
MULTICELLS			
Multi LCs	0	0	0
Multiple jigsaws	0	0	0
polyhedral (Bozarth)	0	0	2394
decorated polyhedral (4-8 sides)	0	0	0

Site: Bakr Awa / Shahrizor offsite								
Sample	**P021**	**P004**	**P020**	**P003**	**P014**	**P013**	**P012**	**P002**
	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm
MULTICELLS								
Hairbase	0	0	0	0	0	0	0	0
cf oak	0	0	0	0	1	0	0	0
Silica aggregates	0	0	0	0	0	0	0	0
Palisade/mesophyll (Bozarth)	0	0	0	0	0	0	0	0
Favose (large)	0	0	0	0	0	0	0	0
Favose (small)	0	0	0	0	0	0	0	0
Honeycomb favose	0	0	0	0	0	0	0	0
Indet dicot multicell	2	1	2	0	0	0	4	0
?Vitis sp	0	0	0	0	0	0	0	0
TOTAL DICOT MC	4	3	2	0	1	0	4	0
TOTAL DICOTS	130	96	66	50	18	23	63	43
OTHER								
Very long sinuate LC (fern)	0	0	0	0	0	0	0	0
Stomata with uneven dentritic LC	0	0	0	0	0	0	0	0
Sponge spicules	0	6	0	0	7	12	8	12
Diatoms	0	0	0	0	0	1	1	0
	P021: 5.4m/west OST1-1	**P004: 5.1m/east OST1-1**	**P020: 5m/west OST1-1**	**P003: 4.9m/east OST1-1**	**P014: 5.2m/west OST1-1a**	**P013: 4.9m/west OST1-1a**	**P012: 4.6m/west OST1-2**	**P002: 4.5m/east OST1-2**
TOTAL SILICA CONTENT	0.02	0.4	0.1	0.4	0.3	0.3	0.3	0.4
TOTAL SINGLE CELLS	280	129	135	118	66	94	179	152
TOTAL MULTICELLS	6	7	5	6	10	3	9	1
TOTAL PHYTOLITHS	286	136	140	124	77	97	188	153

Site: Bakr Awa / Shahrizor offsite							
Sample	**P026**	**P025**	**P010**	**P024**	**P009**	**P019**	**P011**
	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm
MULTICELLS							
Hairbase	1	0	0	2	0	0	0
cf oak	1	0	1	0	0	0	0
Silica aggregates	4	17	0	8	0	2	0
Palisade/mesophyll (Bozarth)	0	0	0	0	0	0	0
Favose (large)	0	0	0	1	0	0	0
Favose (small)	0	0	0	0	0	0	0
Honeycomb favose	0	0	0	0	0	0	0
Indet dicot multicell	6	7	0	5	1	2	2
?Vitis sp	0	0	0	0	0	0	0
TOTAL DICOT MC	12	25	1	20	1	4	2
TOTAL DICOTS	209	597	71	150	125	65	73
OTHER							
Very long sinuate LC (fern)	0	0	0	0	0	0	0
Stomata with uneven dentritic LC	0	0	0	0	0	0	0
Sponge spicules	0	0	13	0	14	0	10
Diatoms	6	5	0	4	0	1	2
	P026: 3.8m/west OST1-2	**P025: 3.0m/west OST1-2**	**P010: 2.7m/east OST1-2**	**P024: 2.5m/west OST1-2**	**P009: 2m/east OST1-2**	**P019: 4.5m/west OST1-3**	**P011: 4.3m/west OST1-3**
TOTAL SILICA CONTENT	0.04	0.03	0.3	0.01	0.2	0.04	0.3
TOTAL SINGLE CELLS	587	2050	212	345	628	162	196
TOTAL MULTICELLS	37	83	2	61	3	7	4
TOTAL PHYTOLITHS	624	2133	214	406	630	169	200

Site: Bakr Awa / Shahrizor offsite			
Sample	**P018**	**P001**	**P023**
	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm
MULTICELLS			
Hairbase	0	0	0
cf oak	0	0	1197
Silica aggregates	2	0	9577
Palisade/mesophyll (Bozarth)	0	0	0
Favose (large)	0	0	0
Favose (small)	0	1	1197
Honeycomb favose	0	0	0
Indet dicot multicell	2	0	5986
?Vitis sp	0	0	0
TOTAL DICOT MC	4	1	20351
TOTAL DICOTS	34	58	2718708
OTHER			
Very long sinuate LC (fern)	0	0	0
Stomata with uneven dentritic LC	0	0	0
Sponge spicules	0	5	58660
Diatoms	0	1	0
	P018: 4.2m/west OST1-3	**P001: 3.4/east OST1-3**	**P023: 1.8m/west OST1-5**
TOTAL SILICA CONTENT	0.03	0.3	0.04
TOTAL SINGLE CELLS	102	128	11761315
TOTAL MULTICELLS	8	6	64646
TOTAL PHYTOLITHS	110	134	11825960

Site: Bakr Awa / Shahrizor offsite								
Sample	**P021**	**P004**	**P020**	**P003**	**P014**	**P013**	**P012**	**P002**
	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm
WETLAND PLANTS								
Reeds/phragmites	0	0	0	0	0	0	0	0
Sedges	2	3	0	1	1	1	4	0
Total wetland plants	2	3	0	1	1	1	4	0
CEREALS								
Total wheat husks	0	0	0	0	0	0	0	0
Total cereal husks	0	0	0	0	1	0	0	0
Agri weeds/wild grass husks	0	0	0	0	0	0	0	0
Wild grass stems	0	0	0	0	0	0	0	0
Total wild grass/weeds	0	0	0	0	0	0	0	0
Total grasses	0	0	0	0	1	0	0	0
SINGLE CELLS (SHORT CELLS)								
Bilobes/quadralobes (mainly panicoid	2	0	2	1	0	0	0	1
Saddles (mainly chloridoid C4)	0	0	0	0	0	0	0	0
Rondels (mainly pooid C3)	4	3	0	4	1	2	0	13
Aundinoid bilobes/saddles/cones (C3)	38	9	14	6	10	10	39	23
DICOTS								
Leaf	36	0	28	5	2	4	9	2
Wood/bark	70	49	29	26	10	15	39	29
?Fruit								
Leaf MC	2	0	0	0	0	0	0	0
Wood/bark MC	0	0	0	0	1	0	0	0
Sedge/reeds SC	38	9	14	6	10	10	39	23

Site: Bakr Awa / Shahrizor offsite							
Sample	**P026**	**P025**	**P010**	**P024**	**P009**	**P019**	**P011**
	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm
WETLAND PLANTS							
Reeds/phragmites	1	1	0	0	0	0	0
Sedges	6	13	0	8	1	0	1
Total wetland plants	7	14	0	8	1	0	1
CEREALS							
Total wheat husks	0	1	0	0	0	0	0
Total cereal husks	0	2	0	0	0	0	0
Agri weeds/wild grass husks	2	1	0	4	0	0	0
Wild grass stems	0	0	0	1	0	1	0
Total wild grass/weeds	2	1	0	5	0	1	0
Total grasses	2	3	0	9	0	1	0
SINGLE CELLS (SHORT CELLS)							
Bilobes/quadralobes (mainly panicoid	0	0	0	1	0	0	0
Saddles (mainly chloridoid C4)	1	0	0	0	2	0	1
Rondels (mainly pooid C3)	46	72	6	15	46	1	3
Aundinoid bilobes/saddles/cones (C3)	78	379	37	80	157	30	21
DICOTS							
Leaf	77	261	11	38	24	0	13
Wood/bark	82	245	52	62	72	14	40
?Fruit							
Leaf MC	1	1	0	6	0	0	0
Wood/bark MC	5	17	1	8	0	2	0
Sedge/reeds SC	78	379	37	80	157	30	21

Site: Bakr Awa / Shahrizor offsite			
Sample	**P018**	**P001**	**P023**
	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm
WETLAND PLANTS			
Reeds/phragmites	0	2	1197
Sedges	1	1	5986
Total wetland plants	1	3	7183
CEREALS			
Total wheat husks	0	0	0
Total cereal husks	0	0	0
Agri weeds/wild grass husks	0	0	7183
Wild grass stems	0	0	2394
Total wild grass/weeds	0	0	9577
Total grasses	0	0	9577
SINGLE CELLS (SHORT CELLS)			
Bilobes/quadralobes (mainly panicoid	1	0	0
Saddles (mainly chloridoid C4)	0	0	29330
Rondels (mainly pooid C3)	8	3	938559
Aundinoid bilobes/saddles/cones (C3)	15	20	1818458
DICOTS			
Leaf	8	11	1114539
Wood/bark	14	23	791909
?Fruit			
Leaf MC	0	0	2394
Wood/bark MC	2	0	10774
Sedge/reeds SC	15	20	1818458

I.2 Onsite samples

Bakr Awa Onsite							
Sample	112/2317	114/2293	109/2269	115/2306	111/2279	110/2274	101/2232
	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm
MONOCOTS							
SINGLE CELLS							
Psilate long cell	405952	632796	640836	5690841	510754	134069	289136
Sinuate long cell	85464	105466	25296	523296	96629	14664	46635
Dentritic long cell	459367	137106	438467	1308239	227769	50276	111924
Trapezoid sinuate/crenate	149561	73826	75888	327060	0	12569	121251
Papillae	64098	158199	75888	0	27608	14664	46635
?Emmer papillae (stubble)	10683	31640	0	65412	0	0	0
Keystone bulliform	21366	31640	8432	392472	34510	6284	447695
Bilobe Chloridoid (C4)	0	0	0	0	0	0	0
Bilobe Panicoid (Most C4)	0	0	0	0	6902	10474	0
Bilobe Aruninoid (Most C3)	0	0	0	0	0	0	0
Bilobe indet	10683	0	0	65412	62119	4190	0
Saddle Chloridoid	10683	10547	8432	65412	0	23043	65289
Saddle Aruninoid	0	0	0	0	0	0	0
Saddle indet	0	21093	16864	719532	55217	31422	74616
Polylobate	21366	10547	25296	65412	6902	4190	9327
Quadralobe	10683	0	0	65412	0	0	9327
Rondel	1239223	738262	666132	7129905	634992	199009	401060
Flat tower	0	0	16864	65412	13804	2095	0
Horned tower	10683	10547	50592	65412	20706	6284	102597
Elliptical psilate	53415	0	42160	196236	13804	0	0
rectangular psilate (small)	32049	21093	0	523296	13804	4190	9327
Grass SC indet	0	0	0	0	0	0	0
Echinate long cell	213659	73826	126481	1439063	124238	25138	167886
Crenate LC	0	10547	0	0	0	0	0

Bakr Awa Onsite							
Sample	17/2217	107/2272	106/2264	108/2264-1	16/2218	21/2205	20/2205
	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm
MONOCOTS							
SINGLE CELLS							
Psilate long cell	269163	188300	465292	583529	69973	72466	92814
Sinuate long cell	19505	8431	83905	70024	5941	9251	15707
Dentritic long cell	89721	115228	137299	175059	16503	29295	49977
Trapezoid sinuate/crenate	66315	22484	68650	140047	7921	9251	15707
Papillae	19505	25294	30511	128376	2640	2313	7140
?Emmer papillae (stubble)	0	0	0	0	0	0	0
Keystone bulliform	39009	16863	45766	23341	8582	10022	8567
Bilobe Chloridoid (C4)	0	0	7628	0	0	0	0
Bilobe Panicoid (Most C4)	3901	0	38139	11671	1320	0	0
Bilobe Aruninoid (Most C3)	0	0	0	0	0	0	0
Bilobe indet	7802	2810	30511	11671	1320	0	0
Saddle Chloridoid	3901	0	0	128376	3301	0	11423
Saddle Aruninoid	0	2810	0	0	0	0	0
Saddle indet	3901	2810	7628	93365	0	1542	5712
Polylobate	3901	2810	7628	23341	1980	1542	1428
Quadralobe	3901	0	22883	35012	0	3855	1428
Rondel	331577	185490	854306	1167059	43568	37004	117089
Flat tower	0	5621	15255	0	1980	1542	5712
Horned tower	7802	8431	15255	93365	660	2313	5712
Elliptical psilate	0	16863	22883	11671	3301	2313	2856
rectangular psilate (small)	7802	11242	38139	58353	1980	8480	2856
Grass SC indet	0	0	0	0	0	0	0
Echinate long cell	50712	36536	91533	151718	11222	9251	18563
Crenate LC	3901	0	7628	0	0	0	1428

Bakr Awa Onsite							
Sample	18/2205	19/2205	105/2238	102/2227	104/2237	103/2236	113/2294
	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm
MONOCOTS							
SINGLE CELLS							
Psilate long cell	126525	67260	600999	281759	311929	336497	315429
Sinuate long cell	23307	20418	64393	42054	94693	103537	45061
Dentritic long cell	69922	34831	96589	63080	161534	168248	100521
Trapezoid sinuate/crenate	16648	14413	42929	21027	66842	64711	62393
Papillae	9989	3603	5366	12616	16710	77653	27730
?Emmer papillae (stubble)	0	0	0	8411	0	0	0
Keystone bulliform	9989	22820	16098	25232	105833	58240	13865
Bilobe Chloridoid (C4)	0	0	0	12616	0	0	0
Bilobe Panicoid (Most C4)	4994	1201	0	25232	5570	12942	0
Bilobe Aruninoid (Most C3)	0	0	0	16821	0	0	0
Bilobe indet	3330	2402	5366	16821	11140	6471	0
Saddle Chloridoid	6659	4804	0	8411	22281	0	0
Saddle Aruninoid	0	0	0	0	0	0	0
Saddle indet	1665	2402	32196	25232	11140	0	10399
Polylobate	0	3603	5366	4205	16710	45298	3466
Quadralobe	3330	0	0	4205	0	6471	0
Rondel	148168	72064	499044	496233	334209	718291	329294
Flat tower	3330	0	0	29438	0	0	6933
Horned tower	1665	3603	5366	25232	16710	6471	3466
Elliptical psilate	1665	2402	16098	16821	11140	19413	0
rectangular psilate (small)	9989	9609	48295	8411	44561	32355	20798
Grass SC indet	0	0	0	0	0	0	0
Echinate long cell	28302	21619	75125	42054	100263	155306	31196
Crenate LC	0	0	0	0	0	0	6933

Bakr Awa Onsite		
Sample	117/2294	02/1159
	n. phyt. per gm	n. phyt. per gm
MONOCOTS		
SINGLE CELLS		
Psilate long cell	505210	63817
Sinuate long cell	104250	10816
Dentritic long cell	128307	16225
Trapezoid sinuate/crenate	184442	12980
Papillae	88211	10816
?Emmer papillae (stubble)	0	0
Keystone bulliform	40096	8653
Bilobe Chloridoid (C4)	0	0
Bilobe Panicoid (Most C4)	0	0
Bilobe Aruninoid (Most C3)	0	0
Bilobe indet	8019	3245
Saddle Chloridoid	0	3245
Saddle Aruninoid	0	0
Saddle indet	8019	4327
Polylobate	16038	1082
Quadralobe	0	0
Rondel	473133	89776
Flat tower	16038	0
Horned tower	16038	1082
Elliptical psilate	32077	0
rectangular psilate (small)	96230	4327
Grass SC indet	0	0
Echinate long cell	88211	10816
Crenate LC	8019	2163

Bakr Awa Onsite							
Sample	**112/2317**	**114/2293**	**109/2269**	**115/2306**	**111/2279**	**110/2274**	**101/2232**
	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm
MONOCOTS							
SINGLE CELLS							
Psilate long cell rod	299123	232025	177073	392472	117335	33517	130578
Echinate long cell rod	181610	0	33728	196236	20706	2095	102597
Cylindric psilate long cell	0	0	0	0	0	0	0
Psilate assymetrical LC	235025	200385	50592	981180	110433	60750	167886
Echinate assymetrical LC	21366	21093	0	130824	27608	8379	55962
Psilate LC w/projections on 1 side	0	0	16864	0	0	2095	0
Prickle hairs	10683	73826	42160	65412	27608	2095	0
Tricomes	74781	116013	59024	719532	41413	12569	55962
Hairs	117513	63280	84321	196236	0	20948	55962
Bulliforms	170927	537877	143345	850356	151846	50276	587599
?Bulliforms (echinate semi-sphere)	32049	0	0	65412	13804	0	46635
Stomata	32049	0	8432	0	27608	2095	37308
Tetracytic stomata (?Scirpus)	21366	10547	16864	0	0	0	0
Sedge cones	117513	421864	210801	784944	151846	29328	111924
Globular echinate cf date palm	10683	10547	8432	130824	13804	2095	0
Globular spinulose cf Doum palm	0	0	0	0	0	0	0
Trapezoid	53415	10547	8432	65412	34510	6284	18654
Indet monocot SC	32049	84373	50592	981180	34510	20948	46635
Total monocot single cells	4209086	3849508	3128292	24267841	2622793	796034	3320402
MULTICELLS							
Silica skeleton psilate LC	366273	876990	285698	82626	151246	151472	270482
Silica skeleton sinuate LC	12209	190650	17856	55084	25208	15147	338103
Silica skeleton echinate LC	36627	0	44640	27542	0	0	135241
Indet monocot leaf/stem	146509	571950	80353	75740	54617	83310	135241

Bakr Awa Onsite							
Sample	17/2217	107/2272	106/2264	108/2264-1	16/2218	21/2205	20/2205
	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm
MONOCOTS							
SINGLE CELLS							
Psilate long cell rod	66315	33725	137299	291765	9242	3084	14279
Echinate long cell rod	19505	5621	53394	23341	3301	2313	7140
Cylindric psilate long cell	0	0	0	11671	0	0	0
Psilate assymetrical LC	58514	44967	114416	186729	7261	8480	27130
Echinate assymetrical LC	7802	11242	15255	0	1980	3084	5712
Psilate LC w/projections on 1 side	0	11242	0	0	0	771	0
Prickle hairs	19505	50588	53394	58353	1320	771	0
Tricomes	42910	30915	22883	58353	3301	7709	15707
Hairs	3901	2810	68650	93365	660	0	2856
Bulliforms	140433	106797	91533	198400	17823	23127	27130
?Bulliforms (echinate semi-sphere)	11703	5621	7628	11671	1980	1542	1428
Stomata	0	0	7628	11671	0	0	0
Tetracytic stomata (?Scirpus)	0	0	7628	0	0	0	0
Sedge cones	93622	50588	274599	256753	18483	18502	58544
Globular echinate cf date palm	0	2810	0	0	0	1542	0
Globular spinulose cf Doum palm	0	0	0	0	0	0	0
Trapezoid	31207	8431	22883	81694	5281	6938	1428
Indet monocot SC	31207	36536	38139	105035	9242	7709	14279
Total monocot single cells	1458939	1053918	2906168	4294776	262069	286008	539751
MULTICELLS							
Silica skeleton psilate LC	163838	50588	313246	271017	24993	16960	31414
Silica skeleton sinuate LC	7802	5621	123061	57056	532	1542	3808
Silica skeleton echinate LC	0	8431	33562	28528	0	1156	1904
Indet monocot leaf/stem	11703	33725	67124	285281	3722	771	952

Bakr Awa Onsite							
Sample	18/2205	19/2205	105/2238	102/2227	104/2237	103/2236	113/2294
	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm
MONOCOTS							
SINGLE CELLS							
Psilate long cell rod	6659	6005	150250	33643	27851	77653	69325
Echinate long cell rod	6659	3603	16098	12616	16710	25884	10399
Cylindric psilate long cell	1665	0	0	0	0	0	0
Psilate assymetrical LC	26637	30027	75125	42054	139254	116480	55460
Echinate assymetrical LC	4994	3603	21464	0	16710	32355	0
Psilate LC w/projections on 1 side	3330	1201	0	4205	5570	6471	0
Prickle hairs	0	4804	0	12616	22281	19413	3466
Tricomes	6659	14413	53661	33643	66842	38827	20798
Hairs	0	0	5366	37848	0	0	6933
Bulliforms	24972	28826	75125	67286	133684	129422	55460
?Bulliforms (echinate semi-sphere)	24972	1201	5366	0	5570	19413	3466
Stomata	0	0	0	0	0	0	0
Tetracytic stomata (?Scirpus)	0	0	0	8411	0	0	0
Sedge cones	36626	55249	59027	54670	256227	187662	93589
Globular echinate cf date palm	1665	1201	5366	0	5570	0	0
Globular spinulose cf Doum palm	0	0	0	0	0	0	0
Trapezoid	9989	6005	53661	37848	27851	19413	31196
Indet monocot SC	16648	13212	64393	21027	61272	32355	38129
Total monocot single cells	640951	456408	2098130	1551779	2116659	2517253	1365705
MULTICELLS							
Silica skeleton psilate LC	14983	8197	166348	142982	38016	97066	30871
Silica skeleton sinuate LC	1873	1171	26830	51065	5431	45298	5145
Silica skeleton echinate LC	3122	390	0	0	1810	19413	1029
Indet monocot leaf/stem	4994	3123	85857	45959	14482	71182	15436

Bakr Awa Onsite		
Sample	**117/2294**	**02/1159**
	n. phyt. per gm	n. phyt. per gm
MONOCOTS		
SINGLE CELLS		
Psilate long cell rod	160384	25959
Echinate long cell rod	48115	8653
Cylindric psilate long cell	8019	1082
Psilate assymetrical LC	152365	14061
Echinate assymetrical LC	8019	3245
Psilate LC w/projections on 1 side	16038	0
Prickle hairs	8019	6490
Tricomes	40096	10816
Hairs	32077	0
Bulliforms	176423	33531
?Bulliforms (echinate semi-sphere)	16038	1082
Stomata	8019	0
Tetracytic stomata (?Scirpus)	0	0
Sedge cones	408979	35694
Globular echinate cf date palm	48115	0
Globular spinulose cf Doum palm	0	0
Trapezoid	24058	6490
Indet monocot SC	96230	7571
Total monocot single cells	3063337	398045
MULTICELLS		
Silica skeleton psilate LC	56863	9039
Silica skeleton sinuate LC	34993	2086
Silica skeleton echinate LC	0	348
Indet monocot leaf/stem	78734	5215

Bakr Awa Onsite							
Sample	112/2317	114/2293	109/2269	115/2306	111/2279	110/2274	101/2232
	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm
MULTICELLS							
Silica skelton LC and stomata	36627	76260	0	0	0	7574	33810
leaf/stem with grass stomata	0	0	8928	0	0	15147	0
leaf/stem with rondels	61045	266910	8928	6885	4201	22721	101431
leaf/stem with bilobes indet	12209	0	0	0	0	0	0
leaf/stem with chloridoid bilobes	0	0	0	0	0	0	0
leaf/stem with panicoid bilobes	0	0	0	0	0	0	0
leaf/stem with arunidoid bilobes	0	0	0	0	0	0	0
Phragmite leaf	24418	0	0	0	0	7574	574775
phragmite stem	0	0	0	6885	0	0	0
leaf/stem with saddles indet	0	0	0	0	4201	0	33810
leaf/stem with choridoid saddles	0	0	0	0	0	0	33810
leaf/stem with arunidoid saddles	0	0	0	0	0	0	0
leaf/stem with quadralobes	0	0	0	0	0	0	0
leaf/stem with bulliforms	61045	152520	35712	13771	0	15147	135241
leaf/stem with crenates	0	0	0	0	0	0	0
square cell leaf/stem	0	0	0	0	0	0	0
multiple bulliforms	0	0	0	13771	4201	37868	101431
Stem with hair	24418	76260	35712	34427	0	0	33810
Assymetrical LCs	61045	343170	44640	61969	21006	83310	169051
Cylindrical (rods) and LCs	85464	76260	116065	110168	33610	83310	304292
Sedge cones	0	152520	35712	13771	12604	68162	101431
Visible mesophyll	0	38130	17856	27542	0	7574	169051
Indet husk	109882	228780	62496	6885	25208	30294	101431
Wheat husk indet	0	0	8928	0	0	0	0
Emmer wheat	0	38130	0	0	0	0	0

Bakr Awa Onsite							
Sample	**17/2217**	**107/2272**	**106/2264**	**108/2264-1**	**16/2218**	**21/2205**	**20/2205**
	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm
MULTICELLS							
Silica skelton LC and stomata	3901	0	33562	14264	532	0	952
leaf/stem with grass stomata	0	2810	0	0	0	0	0
leaf/stem with rondels	3901	2810	22375	99848	0	0	0
leaf/stem with bilobes indet	0	0	0	0	0	0	0
leaf/stem with chloridoid bilobes	0	0	0	0	0	0	0
leaf/stem with panicoid bilobes	0	0	11187	0	0	0	0
leaf/stem with arunidoid bilobes	0	0	0	0	0	0	0
Phragmite leaf	0	0	11187	0	1064	385	0
phragmite stem	0	0	0	0	0	0	952
leaf/stem with saddles indet	0	0	0	14264	532	0	0
leaf/stem with choridoid saddles	0	0	0	0	0	0	0
leaf/stem with arunidoid saddles	0	0	0	0	0	0	0
leaf/stem with quadralobes	0	0	0	0	0	0	0
leaf/stem with bulliforms	7802	5621	0	85584	1064	385	2856
leaf/stem with crenates	0	0	0	0	0	0	0
square cell leaf/stem	0	0	11187	14264	0	0	0
multiple bulliforms	11703	8431	33562	14264	0	1156	0
Stem with hair	0	0	22375	0	532	1156	0
Assymetrical LCs	27306	11242	44749	99848	2127	385	1904
Cylindrical (rods) and LCs	19505	30915	67124	142640	7976	3469	4760
Sedge cones	7802	14052	67124	57056	532	385	952
Visible mesophyll	7802	5621	22375	0	532	0	0
Indet husk	31207	39346	89499	14264	4786	3084	11423
Wheat husk indet	0	5621	0	0	0	385	2856
Emmer wheat	0	0	0	0	0	0	0

Bakr Awa Onsite							
Sample	18/2205	19/2205	105/2238	102/2227	104/2237	103/2236	113/2294
	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm
MULTICELLS							
Silica skelton LC and stomata	624	0	0	0	0	0	0
leaf/stem with grass stomata	0	0	0	0	0	0	0
leaf/stem with rondels	1249	0	0	15320	0	19413	3087
leaf/stem with bilobes indet	0	0	0	0	0	0	0
leaf/stem with chloridoid bilobes	0	0	0	0	0	0	0
leaf/stem with panicoid bilobes	0	0	0	0	0	0	0
leaf/stem with arunidoid bilobes	0	0	0	0	0	0	0
Phragmite leaf	624	390	0	0	1810	6471	0
phragmite stem	0	0	0	5107	0	0	0
leaf/stem with saddles indet	0	0	0	0	0	0	1029
leaf/stem with choridoid saddles	0	0	0	0	0	0	0
leaf/stem with arunidoid saddles	0	0	0	0	0	0	0
leaf/stem with quadralobes	0	0	0	0	0	0	0
leaf/stem with bulliforms	1249	1171	32196	15320	5431	19413	2058
leaf/stem with crenates	0	0	0	0	0	0	0
square cell leaf/stem	624	0	10732	5107	0	6471	0
multiple bulliforms	3122	3513	10732	0	16293	0	2058
Stem with hair	624	390	5366	15320	1810	6471	2058
Assymetrical LCs	2497	2342	64393	51065	10862	71182	2058
Cylindrical (rods) and LCs	6243	3123	59027	51065	14482	51769	7203
Sedge cones	1249	1171	10732	15320	5431	25884	1029
Visible mesophyll	624	2732	5366	0	12672	6471	1029
Indet husk	4994	3123	10732	40852	14482	71182	18523
Wheat husk indet	0	390	0	5107	1810	6471	0
Emmer wheat	624	0	0	0	0	0	0

Bakr Awa Onsite		
Sample	117/2294	02/1159
ı	n. phyt. per gm	n. phyt. per gm
MULTICELLS		
Silica skelton LC and stomata	0	0
leaf/stem with grass stomata	0	0
leaf/stem with rondels	30619	0
leaf/stem with bilobes indet	0	0
leaf/stem with chloridoid bilobes	0	0
leaf/stem with panicoid bilobes	0	0
leaf/stem with arunidoid bilobes	0	0
Phragmite leaf	0	0
phragmite stem	0	0
leaf/stem with saddles indet	0	0
leaf/stem with choridoid saddles	0	0
leaf/stem with arunidoid saddles	0	0
leaf/stem with quadralobes	0	0
leaf/stem with bulliforms	4374	695
leaf/stem with crenates	0	348
square cell leaf/stem	0	348
multiple bulliforms	0	1391
Stem with hair	13122	0
Assymetrical LCs	26245	1391
Cylindrical (rods) and LCs	43741	3477
Sedge cones	13122	695
Visible mesophyll	0	0
Indet husk	65612	3477
Wheat husk indet	0	0
Emmer wheat	0	0

Bakr Awa Onsite							
Sample	**112/2317**	**114/2293**	**109/2269**	**115/2306**	**111/2279**	**110/2274**	**101/2232**
	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm
MULTICELLS							
Durum wheat	0	0	0	0	0	0	0
Einkorn wheat	0	0	0	0	0	0	0
Bread wheat	0	0	0	0	0	0	0
Barley husk	12209	76260	0	0	8403	0	33810
Cereal straw	36627	38130	53568	20656	12604	0	0
Awn	12209	76260	0	6885	8403	0	0
Papillae aggragation (distal)	24418	0	0	0	0	30294	0
Setaria	0	0	0	0	0	0	0
Aegilops (goat grass)	0	0	0	0	0	0	0
Bromus	0	38130	8928	0	0	7574	0
Avena (oat grass)	0	0	17856	0	4201	0	0
Lolium (rye grass)	61045	38130	17856	13771	4201	15147	67621
Scirpus type (tetracytic stomata)	0	0	0	0	0	0	33810
Wild grass husk	85464	266910	17856	20656	16805	53015	169051
Stem (indet grass)	0	38130	0	6885	0	0	0
panicoid bilobes	0	0	0	0	0	0	0
Indet MC	109882	190650	44640	20656	8403	83310	202862
Total monocot MCs	1379628	3851131	964230	626578	399121	817949	3279597
Total monocots	5588713	7700639	4092522	24894419	3021913	1613983	6599999
DICOTS							
SINGLE CELLS							
Globular psilate	10683	42186	16864	0	13804	12569	0
Globular multifaceted	0	0	0	0	0	0	0
Globular verrucate	32049	21093	0	65412	13804	8379	37308
Dicot elongate (oblong)	10683	63280	0	0	6902	0	18654

Bakr Awa Onsite							
Sample	17/2217	107/2272	106/2264	108/2264-1	16/2218	21/2205	20/2205
	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm
MULTICELLS							
Durum wheat	0	0	0	0	0	0	0
Einkorn wheat	0	0	0	0	0	0	0
Bread wheat	0	0	0	0	0	0	0
Barley husk	0	5621	0	28528	0	0	952
Cereal straw	11703	5621	11187	14264	1595	3855	9519
Awn	11703	0	22375	14264	0	1156	952
Papillae aggragation (distal)	0	5621	0	14264	0	385	4760
Setaria	0	0	0	0	0	0	0
Aegilops (goat grass)	3901	0	0	0	0	771	1904
Bromus	0	0	0	0	0	0	4760
Avena (oat grass)	0	0	0	0	0	0	0
Lolium (rye grass)	3901	2810	0	0	0	1156	0
Scirpus type (tetracytic stomata)	0	0	0	0	0	0	0
Wild grass husk	15604	19673	33562	114112	0	0	1904
Stem (indet grass)	0	0	0	0	0	0	0
panicoid bilobes	0	0	0	0	0	0	0
Indet MC	27306	16863	44749	57056	532	771	2856
Total monocot MCs	378388	281045	1085173	1440669	51050	39316	92338
Total monocots	1837327	1334962	3991340	5735445	313119	325325	632090
DICOTS							
SINGLE CELLS							
Globular psilate	0	16863	15255	35012	0	0	2856
Globular multifaceted	0	0	0	0	0	0	0
Globular verrucate	7802	8431	0	35012	660	1542	0
Dicot elongate (oblong)	3901	0	0	11671	0	3855	0

Bakr Awa Onsite							
Sample	**18/2205**	**19/2205**	**105/2238**	**102/2227**	**104/2237**	**103/2236**	**113/2294**
	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm
MULTICELLS							
Durum wheat	0	0	0	0	0	0	0
Einkorn wheat	0	0	0	0	0	0	0
Bread wheat	0	0	0	0	0	0	0
Barley husk	0	0	0	0	0	0	0
Cereal straw	5619	4294	5366	10213	19913	38827	2058
Awn	624	0	0	0	0	6471	2058
Papillae aggragation (distal)	0	390	0	0	1810	6471	1029
Setaria	0	0	0	0	0	6471	0
Aegilops (goat grass)	0	390	5366	5107	1810	6471	0
Bromus	2497	0	0	10213	0	12942	0
Avena (oat grass)	0	0	0	0	0	0	0
Lolium (rye grass)	624	0	0	0	0	6471	0
Scirpus type (tetracytic stomata)	0	0	0	0	0	0	0
Wild grass husk	1249	1171	10732	0	5431	6471	2058
Stem (indet grass)	624	0	0	0	0	0	0
panicoid bilobes	0	0	0	0	0	0	0
Indet MC	624	1171	10732	15320	5431	32355	4116
Total monocot MCs	61182	38645	520508	500438	179220	647109	103934
Total monocots	702133	495052	5588713	5588713	5588713	5588713	5588713
DICOTS							
SINGLE CELLS							
Globular psilate	1665	9609	10732	16821	44561	12942	10399
Globular multifaceted	0	0	0	0	0	0	0
Globular verrucate	0	2402	21464	0	11140	32355	10399
Dicot elongate (oblong)	1665	2402	0	12616	11140	0	0

Bakr Awa Onsite		
Sample	**117/2294**	**02/1159**
	n. phyt. per gm	n. phyt. per gm
MULTICELLS		
Durum wheat	0	0
Einkorn wheat	0	0
Bread wheat	0	0
Barley husk	0	0
Cereal straw	4374	1391
Awn	0	0
Papillae aggragation (distal)	8748	348
Setaria	0	0
Aegilops (goat grass)	13122	348
Bromus	0	348
Avena (oat grass)	0	0
Lolium (rye grass)	0	695
Scirpus type (tetracytic stomata)	0	0
Wild grass husk	30619	1391
Stem (indet grass)	0	0
panicoid bilobes	0	0
Indet MC	39367	1391
Total monocot MCs	463656	34419
Total monocots	5588713	5588713
DICOTS		
SINGLE CELLS		
Globular psilate	32077	0
Globular multifaceted	0	0
Globular verrucate	24058	3245
Dicot elongate (oblong)	0	0

Bakr Awa Onsite							
Sample	**112/2317**	**114/2293**	**109/2269**	**115/2306**	**111/2279**	**110/2274**	**101/2232**
	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm
SINGLE CELLS							
Tracheid	0	21093	0	0	0	4190	46635
Blocks	0	10547	0	0	0	2095	0
Platey	0	0	0	0	0	0	0
Sheet - clear (platelet)	10683	10547	8432	196236	34510	2095	0
Sheet - scrobiculate	10683	10547	8432	523296	20706	4190	111924
Sheet - spotted	10683	0	0	130824	6902	2095	0
Sheet - striated	0	0	0	0	0	0	0
Tricomes (cf Metcalfe)	0	0	0	0	6902	2095	0
Opaque platelets (Bozarth)	0	0	0	0	0	0	0
solid opaque platelets	0	0	0	0	0	0	0
Single polyhedral (Bozarth)	96147	94919	193937	915768	69021	18853	37308
Decorated polyhedral (4-8 sides)	0	10547	16864	0	6902	2095	55962
Single jigsaw	32049	21093	59024	457884	75923	12569	9327
Verrucate	0	10547	8432	0	0	0	18654
Stipa type rondel	0	0	0	0	0	0	0
Scalloped (round)	0	0	0	0	0	0	0
Scalloped (see Bozarth)	10683	0	8432	327060	0	0	111924
Pinaceae tracheids	0	0	0	0	0	0	0
Irregular echinate LC	0	0	0	0	0	0	0
Conifer blocky polyhedral (>8 side)	0	0	0	0	0	0	0
Sclereid	53415	63280	16864	65412	55217	0	102597
Astroscelerid	0	0	0	65412	0	0	9327
large sphere (holes)	0	0	0	0	0	0	0
Stellate	0	10547	8432	0	0	0	0
Indet dicot SC	0	10547	0	65412	0	0	9327

Bakr Awa Onsite							
Sample	17/2217	107/2272	106/2264	108/2264-1	16/2218	21/2205	20/2205
	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm
SINGLE CELLS							
Tracheid	3901	0	7628	23341	0	0	0
Blocks	0	0	0	23341	0	1542	1428
Platey	0	0	0	0	0	0	0
Sheet - clear (platelet)	3901	5621	30511	11671	1320	771	7140
Sheet - scrobiculate	0	2810	30511	23341	1320	0	2856
Sheet - spotted	3901	16863	0	0	0	0	0
Sheet - striated	0	0	0	0	0	0	0
Tricomes (cf Metcalfe)	0	0	0	0	0	0	0
Opaque platelets (Bozarth)	0	0	0	0	0	0	0
solid opaque platelets	0	0	0	0	0	0	0
Single polyhedral (Bozarth)	58514	28104	45766	105035	5941	14647	11423
Decorated polyhedral (4-8 sides)	7802	11242	0	11671	0	1542	5712
Single jigsaw	19505	2810	15255	35012	2640	2313	18563
Verrucate	0	2810	0	11671	0	2313	0
Stipa type rondel	0	0	0	0	0	0	0
Scalloped (round)	0	0	0	0	0	0	0
Scalloped (see Bozarth)	0	11242	0	23341	0	1542	1428
Pinaceae tracheids	0	0	0	0	0	0	0
Irregular echinate LC	0	0	0	0	0	0	0
Conifer blocky polyhedral (>8 side)	0	0	0	0	0	0	0
Sclereid	11703	8431	22883	140047	660	2313	4284
Astroscelerid	0	0	0	0	0	0	0
large sphere (holes)	0	0	0	0	0	0	0
Stellate	0	0	0	0	0	0	0
Indet dicot SC	0	5621	0	11671	660	0	0

Bakr Awa Onsite							
Sample	18/2205	19/2205	105/2238	102/2227	104/2237	103/2236	113/2294
	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm
SINGLE CELLS							
Tracheid	1665	1201	21464	0	5570	32355	3466
Blocks	0	0	5366	0	0	6471	0
Platey	0	0	0	0	0	0	0
Sheet - clear (platelet)	0	1201	0	12616	5570	12942	0
Sheet - scrobiculate	4994	2402	16098	16821	11140	19413	3466
Sheet - spotted	0	0	16098	4205	0	0	0
Sheet - striated	0	0	0	0	0	0	0
Tricomes (cf Metcalfe)	0	0	0	0	0	0	0
Opaque platelets (Bozarth)	0	0	0	0	0	0	0
solid opaque platelets	0	0	0	0	0	0	0
Single polyhedral (Bozarth)	19978	10810	0	67286	50131	97066	45061
Decorated polyhedral (4-8 sides)	6659	1201	0	4205	5570	6471	3466
Single jigsaw	9989	3603	26830	0	16710	25884	10399
Verrucate	0	0	0	0	0	0	0
Stipa type rondel	0	0	0	0	0	0	0
Scalloped (round)	0	0	0	0	0	0	0
Scalloped (see Bozarth)	6659	2402	0	0	11140	6471	0
Pinaceae tracheids	0	0	0	0	0	0	0
Irregular echinate LC	0	0	0	0	0	0	0
Conifer blocky polyhedral (>8 side)	0	0	0	0	0	0	0
Sclereid	0	1201	5366	4205	5570	0	0
Astroscelerid	0	0	0	0	0	0	0
large sphere (holes)	0	0	0	0	0	0	0
Stellate	0	1201	5366	0	5570	0	0
Indet dicot SC	0	1201	5366	8411	5570	0	0

Bakr Awa Onsite		
Sample	117/2294	02/1159
	n. phyt. per gm	n. phyt. per gm
SINGLE CELLS		
Tracheid	0	3245
Blocks	16038	1082
Platey	8019	0
Sheet - clear (platelet)	16038	0
Sheet - scrobiculate	24058	4327
Sheet - spotted	0	0
Sheet - striated	0	0
Tricomes (cf Metcalfe)	0	0
Opaque platelets (Bozarth)	0	0
solid opaque platelets	0	0
Single polyhedral (Bozarth)	24058	8653
Decorated polyhedral (4-8 sides)	8019	0
Single jigsaw	16038	6490
Verrucate	0	1082
Stipa type rondel	0	0
Scalloped (round)	0	0
Scalloped (see Bozarth)	8019	1082
Pinaceae tracheids	0	0
Irregular echinate LC	0	0
Conifer blocky polyhedral (>8 side)	0	0
Sclereid	8019	2163
Astroscelerid	0	0
large sphere (holes)	0	0
Stellate	0	0
Indet dicot SC	8019	4327

Bakr Awa Onsite							
Sample	112/2317	114/2293	109/2269	115/2306	111/2279	110/2274	101/2232
	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm
Total single dicots	277757	400771	345714	2812715	310594	71224	568945
MULTICELLS							
Multi LCs	0	0	0	0	0	0	67621
Multiple jigsaws	0	0	0	0	0	0	0
polyhedral (Bozarth)	12209	0	0	0	12604	0	135241
decorated polyhedral (4-8 sides)	0	0	0	0	0	0	0
Hairbase	0	0	0	0	4201	0	135241
cf oak	0	0	0	0	0	0	33810
Silica aggregates	36627	152520	8928	13771	12604	15147	33810
Palisade/mesophyll (Bozarth)	0	0	0	0	0	0	0
Favose (large)	0	0	0	0	0	0	0
Favose (small)	0	0	0	0	0	0	0
Honeycomb favose	0	0	0	0	0	0	0
Indet dicot multicell	0	38130	17856	13771	0	7574	33810
?Vitis sp	0	0	0	0	0	0	0
Total dicot MCs	48836	190650	26784	27542	29409	22721	439534
Total dicots	326593	591421	372498	2840257	340003	93945	1008479
OTHER							
Very long sinuate LC (fern)	0	0	0	0	0	0	0
Stomata with uneven dentritic LC	0	0	0	0	0	0	0
Sponge spicules	0	0	0	0	0	0	0
Diatoms	10683	0	25296	0	138042	2095	65289

Bakr Awa Onsite							
Sample	17/2217	107/2272	106/2264	108/2264-1	16/2218	21/2205	20/2205
	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm
Total single dicots	120928	120849	167810	501835	13202	32378	55689
MULTICELLS							
Multi LCs	0	0	0	0	0	0	952
Multiple jigsaws	0	0	0	0	0	0	0
polyhedral (Bozarth)	7802	2810	44749	0	1064	0	0
decorated polyhedral (4-8 sides)	0	0	0	0	0	0	952
Hairbase	0	0	0	0	0	0	0
cf oak	0	0	0	0	0	0	952
Silica aggregates	3901	2810	33562	57056	1595	385	1904
Palisade/mesophyll (Bozarth)	0	0	0	0	0	0	0
Favose (large)	0	0	0	0	0	0	0
Favose (small)	0	0	0	0	0	0	0
Honeycomb favose	0	0	0	0	0	0	0
Indet dicot multicell	3901	2810	0	0	532	385	0
?Vitis sp	0	0	0	0	0	0	0
Total dicot MCs	15604	8431	78311	57056	3191	771	4760
Total dicots	136532	129281	246122	558891	16393	33149	60448
OTHER							
Very long sinuate LC (fern)	0	0	0	0	0	0	0
Stomata with uneven dentritic LC	0	0	0	0	0	0	0
Sponge spicules	0	2810	0	0	0	0	0
Diatoms	39009	0	7628	23341	0	10022	8567

Bakr Awa Onsite							
Sample	18/2205	19/2205	105/2238	102/2227	104/2237	103/2236	113/2294
	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm	n. phyt. per gm
Total single dicots	53274	40836	134152	147188	189385	252372	86656
MULTICELLS							
Multi LCs	0	0	0	5107	0	0	0
Multiple jigsaws	0	0	0	0	0	0	0
polyhedral (Bozarth)	0	0	0	20426	0	0	1029.04462
decorated polyhedral (4-8 sides)	0	390	0	0	960	6471	0
Hairbase	0	0	0	0	0	0	0
cf oak	0	0	0	0	0	0	0
Silica aggregates	624	781	10732	0	1921	0	0
Palisade/mesophyll (Bozarth)	0	0	0	0	0	0	0
Favose (large)	0	0	0	0	0	0	0
Favose (small)	0	0	0	0	0	0	0
Honeycomb favose	0	0	0	0	0	0	0
Indet dicot multicell	624	0	10732	0	0	0	0
?Vitis sp	0	0	0	0	0	0	0
Total dicot MCs	1249	1171	21464	25533	2881	6471	1029
Total dicots	54522	42008	155616	172720	192267	258844	87685
OTHER							
Very long sinuate LC (fern)	0	0	0	0	0	0	0
Stomata with uneven dentritic LC	0	0	0	0	0	0	0
Sponge spicules	0	0	0	0	0	0	0
Diatoms	18313	4804	26830	42054	22281	19413	0

Bakr Awa Onsite		
Sample	**117/2294**	**02/1159**
	n. phyt. per gm	n. phyt. per gm
Total single dicots	192461	35694
MULTICELLS		
Multi LCs	0	0
Multiple jigsaws	0	0
polyhedral (Bozarth)	8748	0
decorated polyhedral (4-8 sides)	0	0
Hairbase	0	0
cf oak	0	348
Silica aggregates	4374	0
Palisade/mesophyll (Bozarth)	0	0
Favose (large)	0	0
Favose (small)	0	0
Honeycomb favose	0	0
Indet dicot multicell	4374	0
?Vitis sp	0	0
Total dicot MCs	17496	348
Total dicots	209957	36042
OTHER		
Very long sinuate LC (fern)	0	0
Stomata with uneven dentritic LC	0	0
Sponge spicules	0	0
Diatoms	8019	0

Sample and date	112/2317: EBA floor (ED)	114/2293: EBA floor (ED/Akk)	109/2269: Akkadian floor (with shrine)	115/2306: white layer on stone pavement of shrine	111/2279: Akkadian fireplace (near shrine)	110/2274: Akkadian fireplace (near shrine)	101/2232: Late 3rd millennium floor level
TOTAL SILICA	15.4	41.7	16	72.5	12.3	8.4	38.2
TOTAL PHYTOLITHS (COUNT)	5915307	8292059.9	4465020.53	27734675.37	3361915.847	1707928.073	7608477.919
TOTAL SILICA (OTHER)	10683	0	25296	0	138042	2095	65289
WETLAND PLANTS							
REEDS/PHRAGMITES	24418	0	0	6885	0	7574	574775
SEDGES	85464	228780	151777	123938	46214	151472	439534
TOTAL WETLAND PLANTS	109882	228780	151777	130824	46214	159046	1014308
CEREALS	122091	343170	71424	6885	33610	30294	135241
WHEAT	0	38130	8928	0	0	0	0
BARLEY							
Wild grass stems	0	38130	8928	6885	0	15147	33810
AGRICULTURAL WEEDS/WILD GRASSES	146509	343170	62496	34427	25208	75736	236672
TOTAL WEEDS	146509	381300	71424	41313	25208	90883	270482
TOTAL GRASSES AND STRAW	598246	1487070	464259	227221	214265	242355	980498
DICOTS (ADJUSTED)	4898900	8871312	5587476	42603849	5100041	1409174	15127184
TOTAL SINGLE CELLS	4486843	4250279	3474006	27080556	2933386	867258	3889348
TOTAL MULTICELLS	1428464	4041781	991014	654120	428529	840670	3719130

Sample and date	17/2217: Ur III ashy floor	107/2272: Under OB grave, room 102	106/2264: Oldest OB floor, room 103 OB house	108/2264-1: OB pot contents, from oldest OB floor	16/2218: OB floor (from section)	21/2205: Edge of OB floor	20/2205: Depression in OB floor
TOTAL SILICA	8.6	5.5	17.9	11.7	2.3	1.9	2.8
TOTAL PHYTOLITHS (COUNT)	1973859.029	1464242.912	4237461.752	6294336.11	329511.8427	358473.7035	692538.2666
TOTAL SILICA (OTHER)	39009	2810	7628	23341	0	10022	8567
WETLAND PLANTS							
REEDS/PHRAGMITES	0	0	11187	0	1064	385	952
SEDGES	27306	44967	134248	199697	8508	3855	5712
TOTAL WETLAND PLANTS	27306	44967	145436	199697	9572	4240	6664
CEREALS	31207	50588	89499	42792	4786	3469	15231
WHEAT	0	5621	0	0	0	385	2856
BARLEY							
Wild grass stems	0	2810	0	0	0	0	0
AGRICULTURAL WEEDS/WILD GRASSES	23405	22484	33562	114112	0	1927	8567
TOTAL WEEDS	23405	25294	33562	114112	0	1927	8567
TOTAL GRASSES AND STRAW	206748	92745	514618	484978	27120	25440	55213
DICOTS (ADJUSTED)	2047976	1939208	3691824	8383371	245896	497238	906725
TOTAL SINGLE CELLS	1579867	1174767	3073978	4796611	275272	318386	595440
TOTAL MULTICELLS	393992	289476	1163484	1497725	54240	40087	97098

Sample and date	18/2205: OB pebble floor - by wall	19/2205: OB pebble floor - centre	105/2238: LBA floor	102/2227: LBA floor	104/2237: LBA floor	103/2236: LBA floor	113/2294: LBA floor
TOTAL SILICA	1.6	2.1	14.8	9.8	10.8	12.8	7.4
TOTAL PHYTOLITHS (COUNT)	756655.5184	537059.7312	5744329.31	5761433.801	5780980.015	5847557.04	5676398.93
TOTAL SILICA (OTHER)	18313	4804	26830	42054	22281	19413	0
WETLAND PLANTS							
REEDS/PHRAGMITES	624	390	0	5107	1810	6471	0
SEDGES	7492	4294	69759	66385	19913	77653	8232
TOTAL WETLAND PLANTS	8116	4684	69759	71491	21724	84124	8232
CEREALS	5619	3513	10732	45959	16293	77653	18523
WHEAT	624	390	0	5107	1810	6471	0
BARLEY							
Wild grass stems	624	0	0	0	0	0	0
AGRICULTURAL WEEDS/WILD GRASSES	4370	1561	16098	15320	7241	38827	2058
TOTAL WEEDS	4994	1561	16098	15320	7241	38827	2058
TOTAL GRASSES AND STRAW	30591	15614	214643	219580	72412	239430	41162
DICOTS (ADJUSTED)	817837	630113	2334237	2590805	2883998	3882653	1315282
TOTAL SINGLE CELLS	694225	497244	2232282	1698967	2306044	2769626	1452361
TOTAL MULTICELLS	62430	39816	541972	525971	182101	653580	104963

Sample and date	117/2294: LBA floor	02/1159: LBA/IA floor
TOTAL SILICA	13.2	2.8
TOTAL PHYTOLITHS (COUNT)	5798670.885	5624755.378
TOTAL SILICA (OTHER)	8019	0
WETLAND PLANTS		
REEDS/PHRAGMITES	0	0
SEDGES	56863	4172
TOTAL WETLAND PLANTS	56863	4172
CEREALS	65612	3477
WHEAT	0	0
BARLEY		
Wild grass stems	0	0
AGRICULTURAL WEEDS/WILD GRASSES	43741	2781
TOTAL WEEDS	43741	2781
TOTAL GRASSES AND STRAW	139972	15645
DICOTS (ADJUSTED)	3149361	540628
TOTAL SINGLE CELLS	3255798	433739
TOTAL MULTICELLS	481152	34767

Sample and date	112/2317: EBA floor (ED)	114/2293: EBA floor (ED/Akk)	109/2269: Akkadian floor (with shrine)	115/2306: white layer on stone pavement of shrine	111/2279: Akkadian fireplace (near shrine)	110/2274: Akkadian fireplace (near shrine)	101/2232: Late 3rd millennium floor level
Bilobes/quadralobes (mainly panicoid C	21366	0	0	130824	69021	14664	9327
Saddles (mainly chloridoid C4)	10683	31640	25296	784944	55217	54465	139905
Rondels (mainly C3)	1249906	748808	733589	7260729	669502	207388	503657
DICOTS							
LEAF	128196	137106	252962	1373651	151846	37707	93270
WOOD/BARK	74781	94919	33728	915768	89727	31422	149232
?FRUIT							
LEAF MC	12209	0	0	0	16805	0	270482
WOOD/ BARK MC	36627	152520	8928	13771	12604	15147	67621

Sample and date	17/2217: Ur III ashy floor	107/2272: Under OB grave, room 102	106/2264: Oldest OB floor, room 103 OB house	108/2264-1: OB pot contents, from oldest OB floor	16/2218: OB floor (from section)	21/2205: Edge of OB floor	20/2205: Depression in OB floor
Bilobes/quadralobes (mainly panicoid C	15604	2810	91533	58353	2640	3855	1428
Saddles (mainly chloridoid C4)	7802	2810	7628	221741	3301	1542	17135
Rondels (mainly C3)	339379	199542	884817	1260423	46209	40858	128512
DICOTS							
LEAF	81919	30915	68650	163388	8582	16960	29986
WOOD/BARK	15604	50588	76277	128376	3301	3855	14279
?FRUIT							
LEAF MC	7802	2810	44749	0	1064	0	0
WOOD/ BARK MC	3901	2810	33562	57056	1595	385	2856

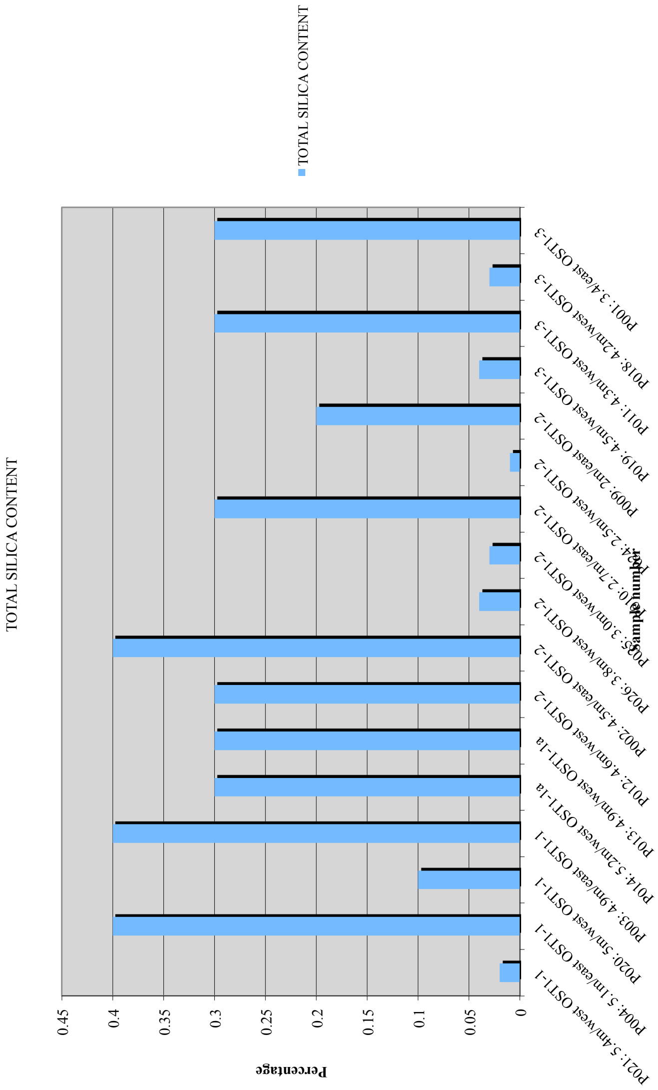
Sample and date	18/2205: OB pebble floor - by wall	19/2205: OB pebble floor - centre	105/2238: LBA floor	102/2227: LBA floor	104/2237: LBA floor	103/2236: LBA floor	113/2294: LBA floor
Bilobes/quadralobes (mainly panicoid C	11654	3603	5366	46259	16710	25884	0
Saddles (mainly chloridoid C4)	8324	7206	32196	33643	33421	0	10399
Rondels (mainly C3)	153162	75668	504410	550903	350920	724762	339693
DICOTS							
LEAF	31631	15614	48295	67286	72412	155306	58926
WOOD/BARK	6659	15614	69759	50464	72412	84124	24264
?FRUIT							
LEAF MC	0	0	0	20426	0	0	1029
WOOD/ BARK MC	624	781	10732	0	1921	0	0

Sample and date	**117/2294: LBA floor**	**02/1159: LBA/IA floor**
Bilobes/quadralobes (mainly panicoid C	8019	3245
Saddles (mainly chloridoid C4)	8019	7571
Rondels (mainly C3)	505210	90858
DICOTS		
LEAF	40096	18388
WOOD/BARK	120288	8653
?FRUIT		
LEAF MC	8748	0
WOOD/ BARK MC	4374	348

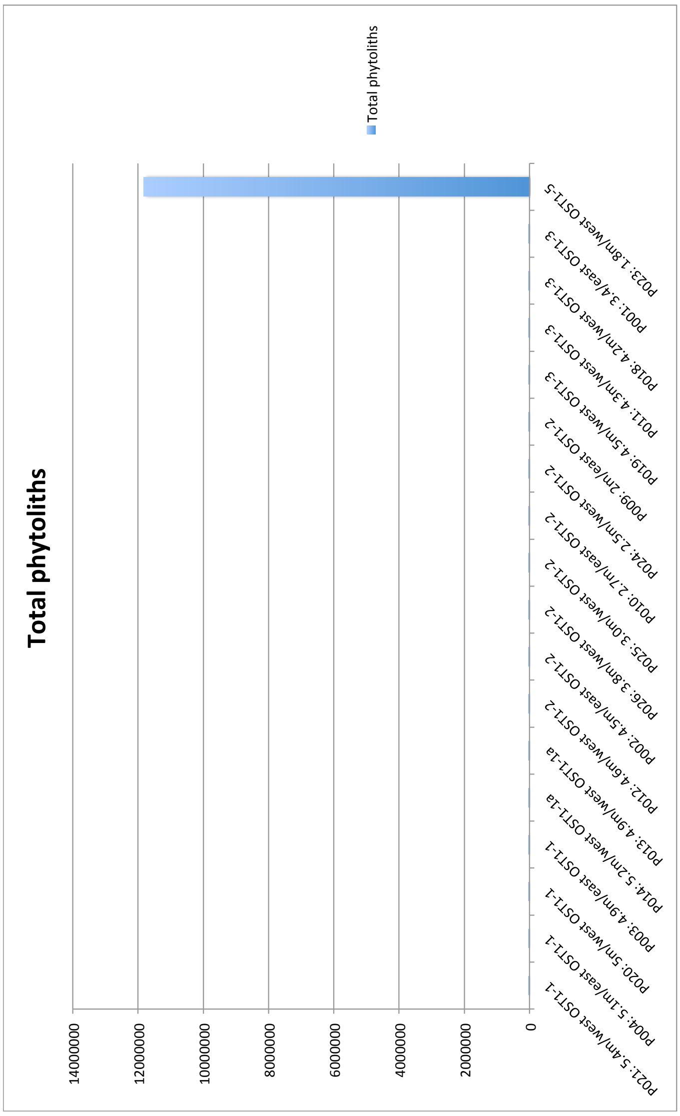
Appendix J

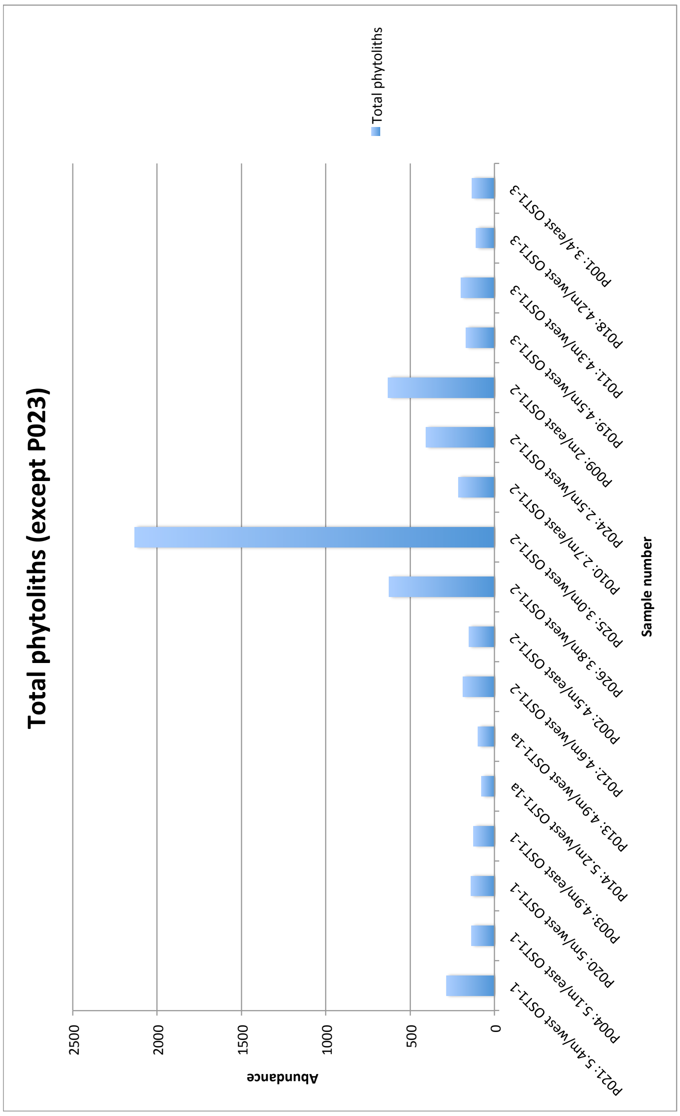
Bakr Awa/Shahrizor phytolith analysis results: histograms

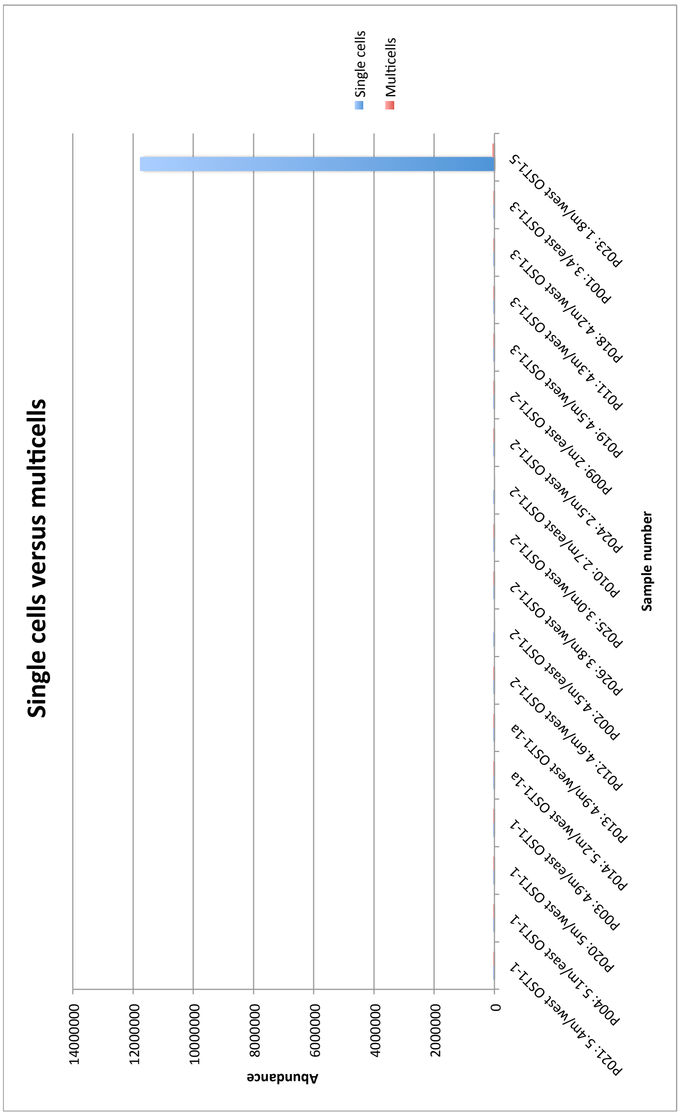
J.1 Offsite histograms



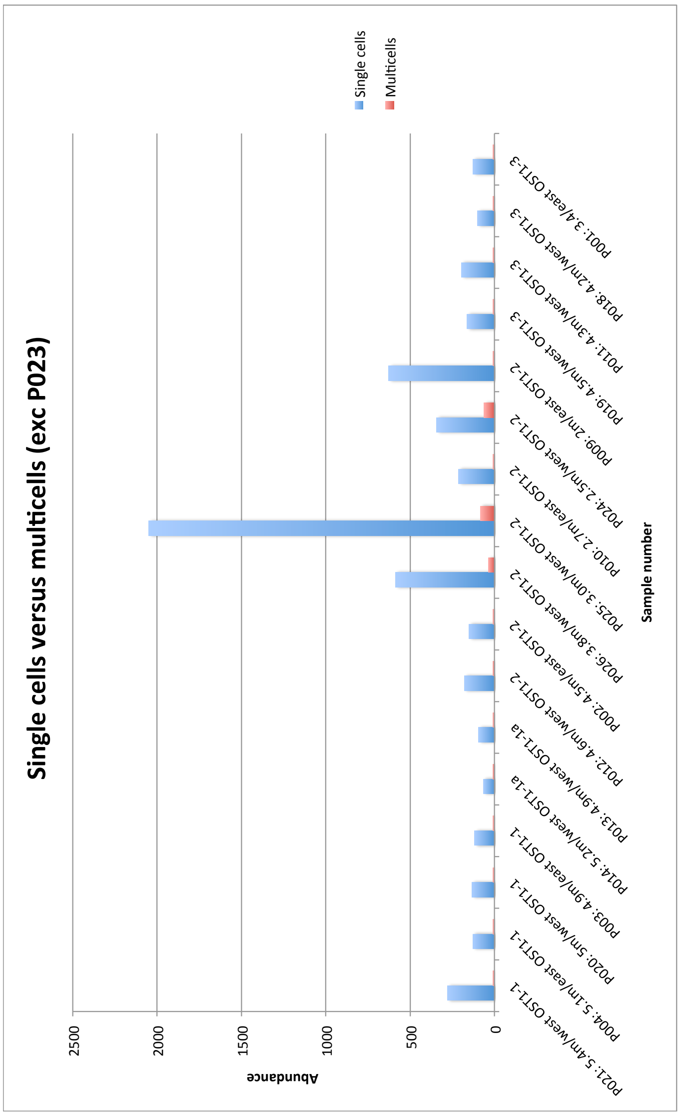
TOTAL SILICA CONTENT
TOTAL SILICA CONTENT
Percentage
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Sample number
P001: 3.4/east OST1-3
P018: 4.2m/west OST1-3
P011: 4.3m/west OST1-3
P019: 4.5m/west OST1-2
P009: 2m/east OST1-2
P010: 2.7m/east OST1-2
P025: 3.0m/west OST1-2
P026: 3.8m/west OST1-2
P002: 4.5m/east OST1-2
P012: 4.6m/west OST1-1a
P013: 4.9m/west OST1-1a
P014: 5.2m/east OST1-1
P003: 4.9m/east OST1-1
P020: 5m/west OST1-1
P004: 5.1m/east OST1-1
P021: 5.4m/west OST1-1


Total phytoliths
14000000
12000000
10000000
8000000
6000000
4000000
2000000
0
P021: 5.4m/west OST1-1
P004: 5.1m/east OST1-1
P020: 5m/west OST1-1
P003: 4.9m/east OST1-1
P014: 5.2m/west OST1-1a
P013: 4.9m/west OST1-1a
P012: 4.6m/west OST1-2
P002: 4.5m/east OST1-2
P026: 3.8m/west OST1-2
P025: 3.0m/west OST1-2
P010: 2.7m/east OST1-2
P024: 2.5m/west OST1-2
P009: 2m/east OST1-2
P019: 4.5m/west OST1-3
P011: 4.3m/west OST1-3
P018: 4.2m/west OST1-3
P001: 3.4/east OST1-3
P023: 1.8m/west OST1-5
Total phytoliths

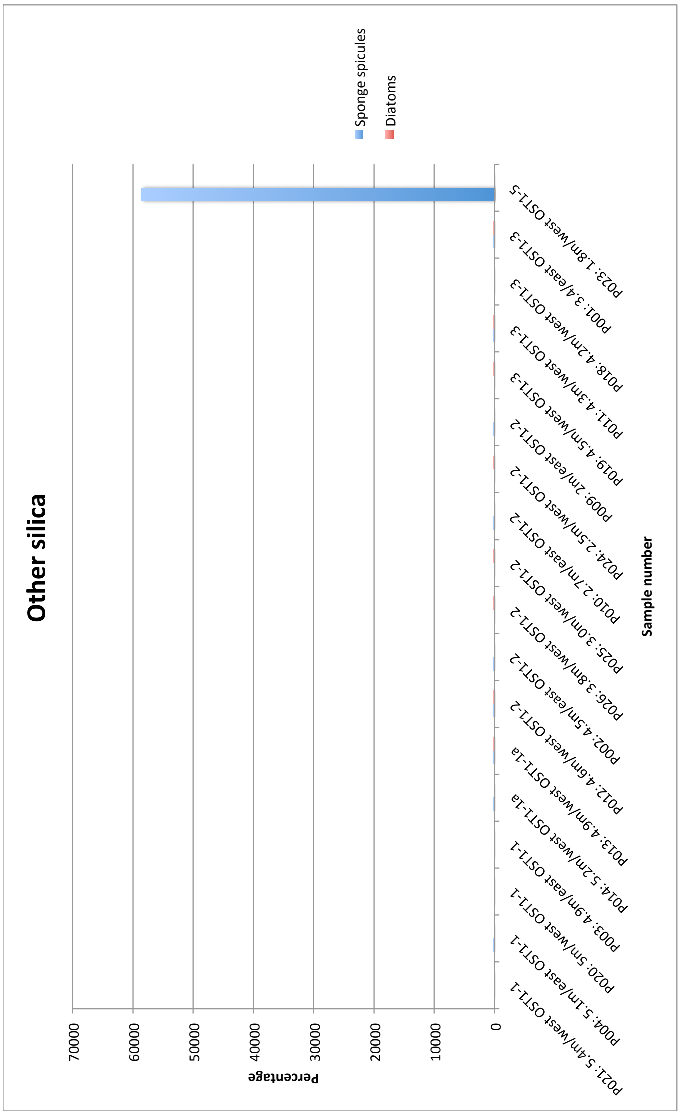

Total phytoliths (except P023)
Total phytoliths
Abundance
Sample number
2500
2000
1500
1000
500
0
P021: 5.4m/west OST1-1
P004: 5.1m/east OST1-1
P020: 5m/west OST1-1
P003: 4.9m/east OST1-1
P014: 5.2m/west OST1-1a
P013: 4.9m/west OST1-1a
P012: 4.6m/west OST1-2
P002: 4.5m/east OST1-2
P026: 3.8m/west OST1-2
P025: 3.0m/west OST1-2
P010: 2.7m/east OST1-2
P024: 2.5m/west OST1-2
P009: 2m/east OST1-2
P019: 4.5m/west OST1-3
P011: 4.3m/west OST1-3
P018: 4.2m/west OST1-3
P001: 3.4/east OST1-3

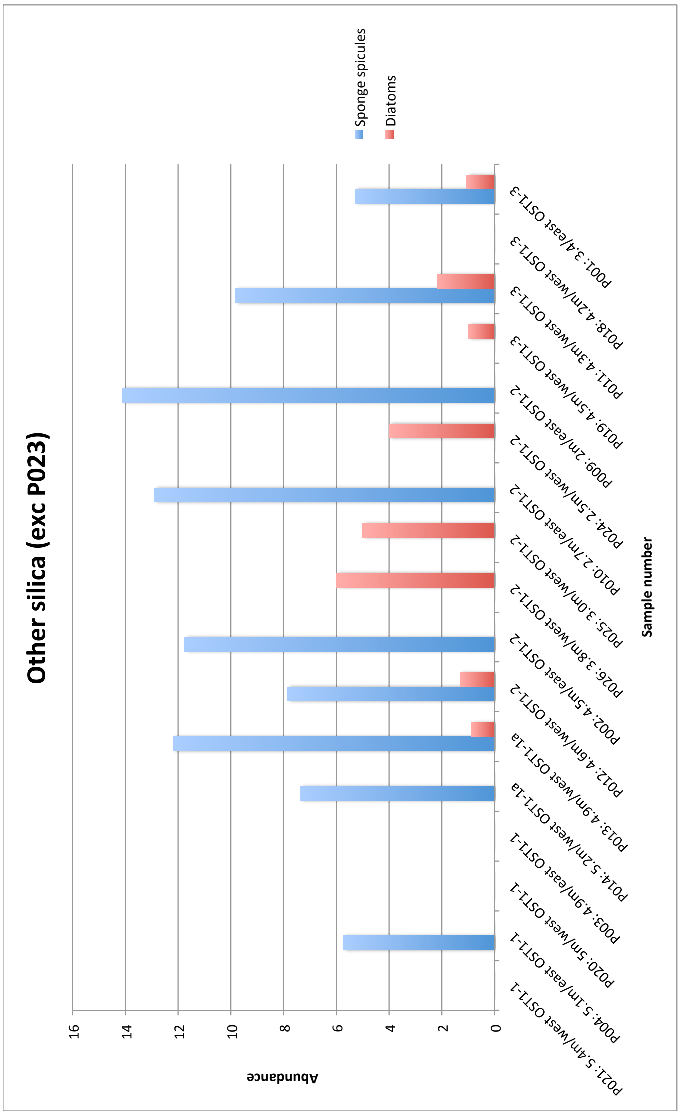


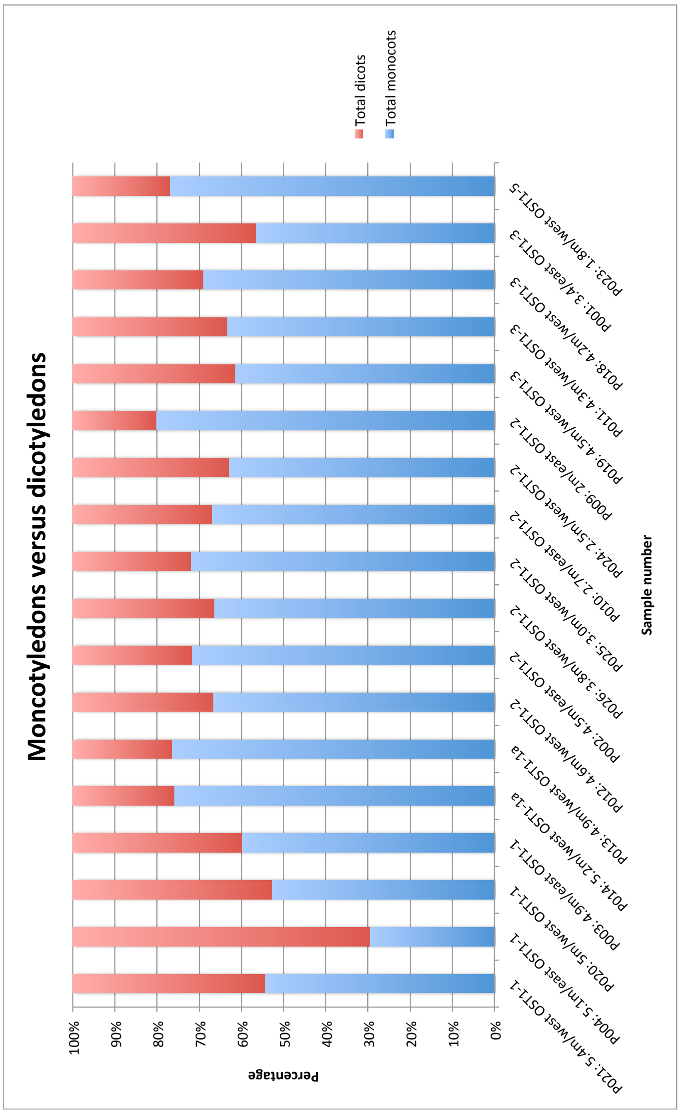
Single cells versus multicells
Abundance
14000000
12000000
10000000
8000000
6000000
4000000
2000000
0
Single cells
Multicells
Sample number
P021: 5.4m/west OST1-1
P004: 5.1m/east OST1-1
P020: 5m/west OST1-1
P003: 4.9m/east OST1-1
P014: 5.2m/west OST1-1a
P013: 4.9m/west OST1-1a
P012: 4.6m/west OST1-2
P002: 4.5m/east OST1-2
P026: 3.8m/west OST1-2
P025: 3.0m/west OST1-2
P010: 2.7m/east OST1-2
P024: 2.5m/west OST1-2
P009: 2m/east OST1-2
P019: 4.5m/west OST1-3
P011: 4.3m/west OST1-3
P018: 4.2m/west OST1-3
P001: 3.4/east OST1-3
P023: 1.8m/west OST1-5

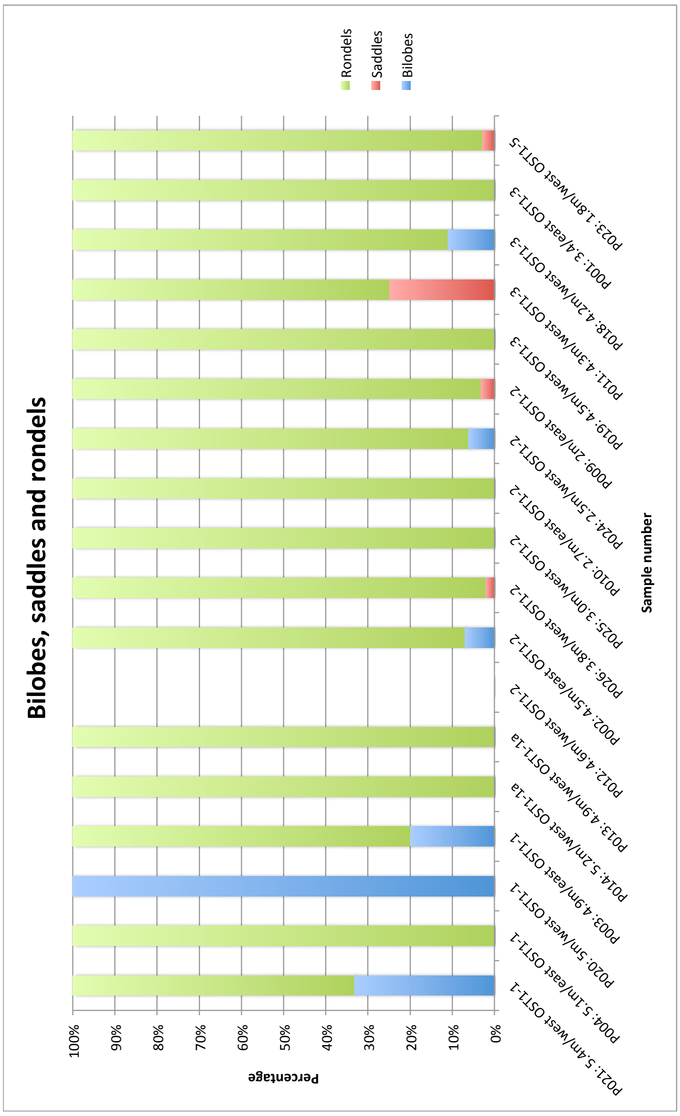


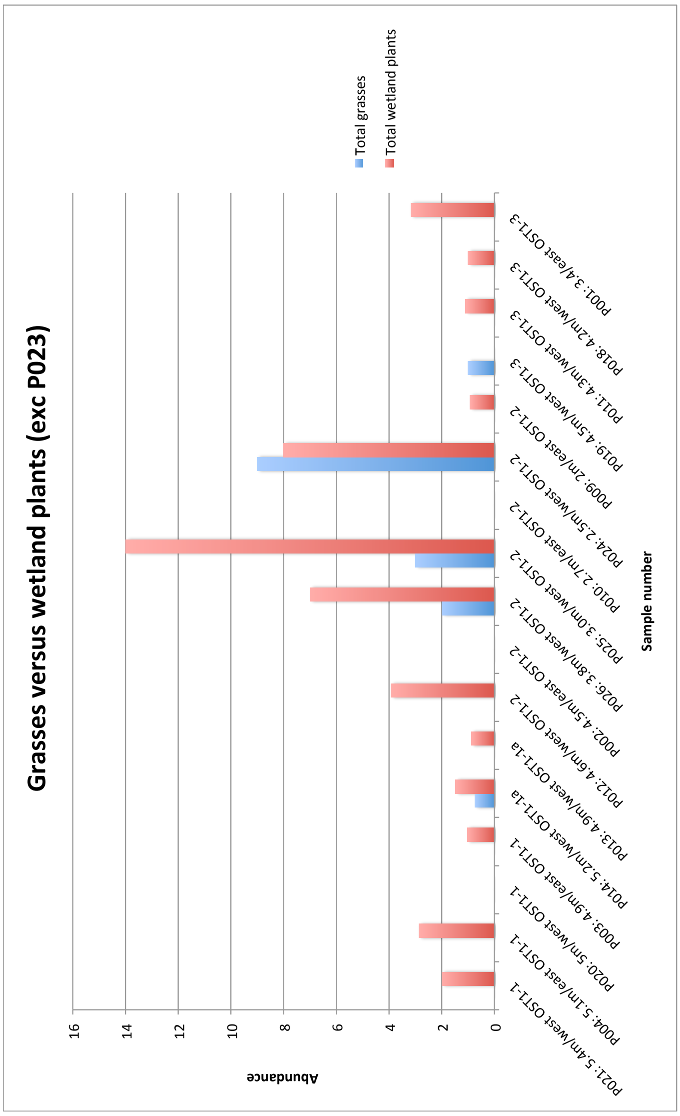
Single cells versus multicells (exc P023)
Abundance
2500
2000
1500
1000
500
0
Single cells
Multicells
P021: 5.4m/west OST1-1
P004: 5.1m/east OST1-1
P020: 5m/west OST1-1
P003: 4.9m/east OST1-1
P014: 5.2m/west OST1-1a
P013: 4.9m/west OST1-1a
P012: 4.6m/west OST1-2
P002: 4.5m/east OST1-2
P026: 3.8m/west OST1-2
P025: 3.0m/west OST1-2
P010: 2.7m/east OST1-2
P024: 2.5m/west OST1-2
P009: 2m/east OST1-2
P019: 4.5m/west OST1-3
P011: 4.3m/west OST1-3
P018: 4.2m/west OST1-3
P001: 3.4/east OST1-3
Sample number


Other silica
Percentage
70000
60000
50000
40000
30000
20000
10000
0
Sponge spicules
Diatoms
Sample number
P021: 5.4m/west OST1-1
P004: 5.1m/east OST1-1
P020: 5m/west OST1-1
P003: 4.9m/east OST1-1
P014: 5.2m/west OST1-1a
P013: 4.9m/west OST1-1a
P012: 4.6m/west OST1-2
P002: 4.5m/east OST1-2
P026: 3.8m/west OST1-2
P025: 3.0m/west OST1-2
P010: 2.7m/east OST1-2
P024: 2.5m/west OST1-2
P009: 2m/east OST1-2
P019: 4.5m/west OST1-3
P011: 4.3m/west OST1-3
P018: 4.2m/west OST1-3
P001: 3.4/east OST1-3
P023: 1.8m/west OST1-5

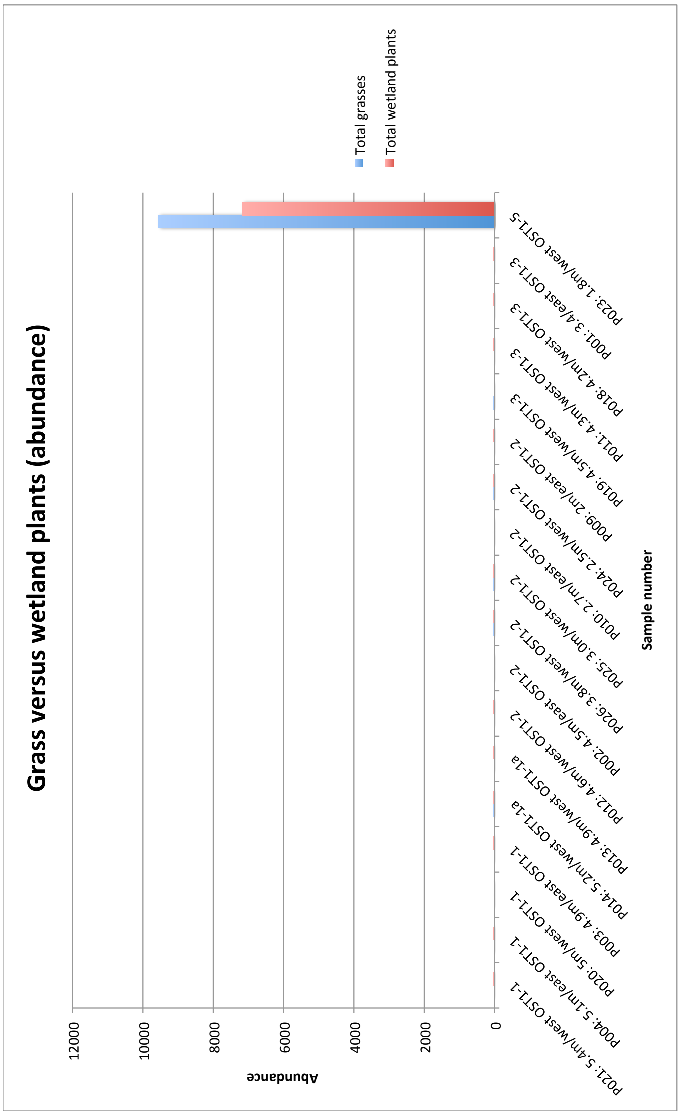

Other silica (exc P023)
Sponge spicules
Diatoms
Abundance
16
14
12
10
8
6
4
2
0
Sample number
P021: 5.4m/west OST1-1
P004: 5.1m/east OST1-1
P020: 5m/west OST1-1
P003: 4.9m/east OST1-1
P014: 5.2m/west OST1-1a
P013: 4.9m/west OST1-1a
P012: 4.6m/west OST1-2
P002: 4.5m/east OST1-2
P026: 3.8m/west OST1-2
P025: 3.0m/west OST1-2
P010: 2.7m/east OST1-2
P024: 2.5m/west OST1-2
P009: 2m/east OST1-2
P019: 4.5m/west OST1-3
P011: 4.3m/west OST1-3
P018: 4.2m/west OST1-3
P001: 3.4/east OST1-3

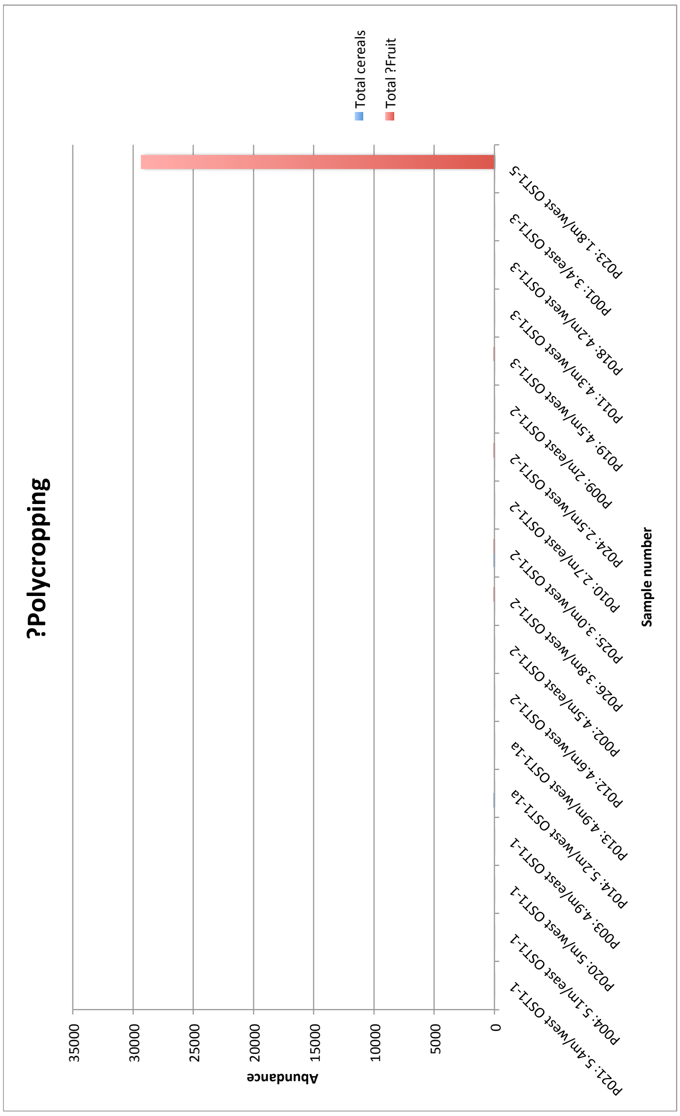

Moncotyledons versus dicotyledons
Percentage
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
P021: 5.4m/west OST1-1
P004: 5.1m/east OST1-1
P020: 5m/west OST1-1
P003: 4.9m/east OST1-1
P014: 5.2m/east OST1-1
P013: 4.9m/west OST1-1a
P012: 4.6m/west OST1-1a
P002: 4.5m/east OST1-2
P026: 3.8m/west OST1-2
P025: 3.0m/west OST1-2
P010: 2.7m/east OST1-2
P024: 2.5m/west OST1-2
P009: 2m/east OST1-2
P019: 4.5m/west OST1-3
P011: 4.3m/west OST1-3
P018: 4.2m/west OST1-3
P001: 3.4/east OST1-3
P023: 1.8m/west OST1-5
Sample number
Total dicots
Total monocots


Bilobes, saddles and rondels
Percentage
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Sample number
P021: 5.4m/west OST1-1
P004: 5.1m/east OST1-1
P020: 5m/west OST1-1
P003: 4.9m/east OST1-1
P014: 5.2m/west OST1-1a
P013: 4.9m/west OST1-1a
P012: 4.6m/west OST1-2
P002: 4.5m/east OST1-2
P026: 3.8m/west OST1-2
P025: 3.0m/west OST1-2
P010: 2.7m/east OST1-2
P024: 2.5m/west OST1-2
P009: 2m/east OST1-2
P019: 4.5m/west OST1-3
P011: 4.3m/west OST1-3
P018: 4.2m/west OST1-3
P001: 3.4/east OST1-3
P023: 1.8m/west OST1-5
Rondels
Saddles
Bilobes

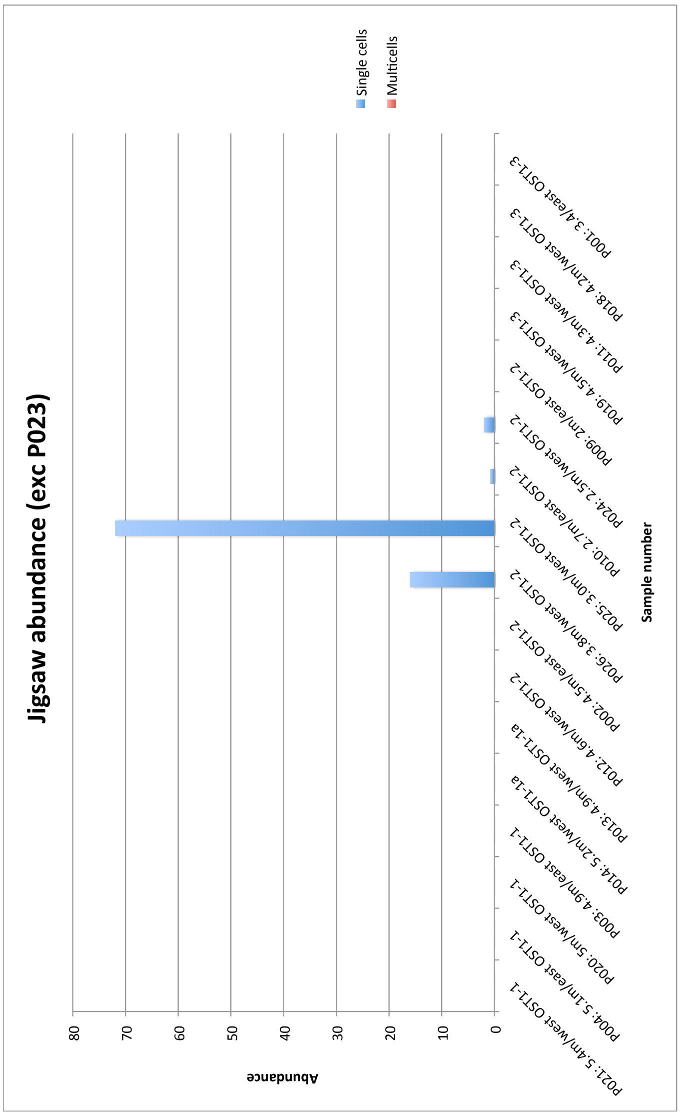


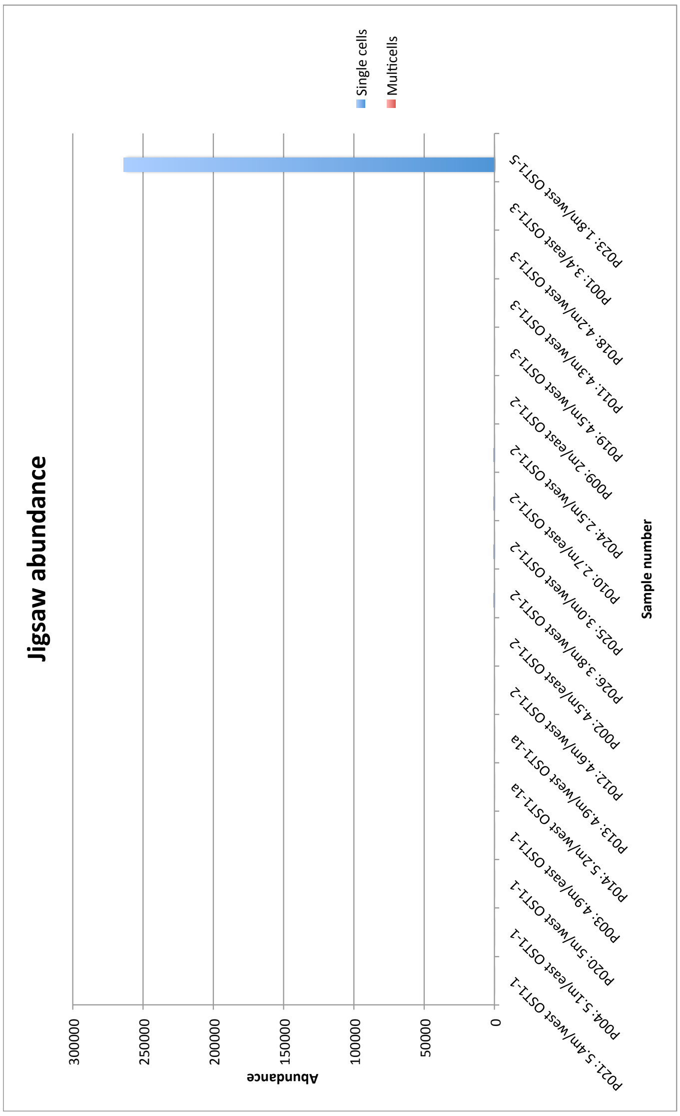
Grasses versus wetland plants (exc P023)
Abundance
0
2
4
6
8
10
12
14
16
Sample number
P021: 5.4m/west OST1-1
P004: 5.1m/east OST1-1
P020: 5m/west OST1-1
P003: 4.9m/east OST1-1
P014: 5.2m/west OST1-1a
P013: 4.9m/west OST1-1a
P012: 4.6m/west OST1-2
P002: 4.5m/east OST1-2
P026: 3.8m/west OST1-2
P025: 3.0m/west OST1-2
P010: 2.7m/east OST1-2
P024: 2.5m/west OST1-2
P009: 2m/east OST1-2
P019: 4.5m/west OST1-3
P011: 4.3m/west OST1-3
P018: 4.2m/west OST1-3
P001: 3.4/east OST1-3
Total grasses
Total wetland plants


Grass versus wetland plants (abundance)
Abundance
0
2000
4000
6000
8000
10000
12000
P021: 5.4m/west OST1-1
P004: 5.1m/east OST1-1
P020: 5m/west OST1-1
P003: 4.9m/east OST1-1
P014: 5.2m/west OST1-1a
P013: 4.9m/west OST1-1a
P012: 4.6m/west OST1-2
P002: 4.5m/east OST1-2
P026: 3.8m/west OST1-2
P025: 3.0m/west OST1-2
P010: 2.7m/east OST1-2
P024: 2.5m/west OST1-2
P009: 2m/east OST1-2
P019: 4.5m/west OST1-3
P011: 4.3m/west OST1-3
P018: 4.2m/west OST1-3
P001: 3.4/east OST1-3
P023: 1.8m/west OST1-5
Sample number
Total grasses
Total wetland plants

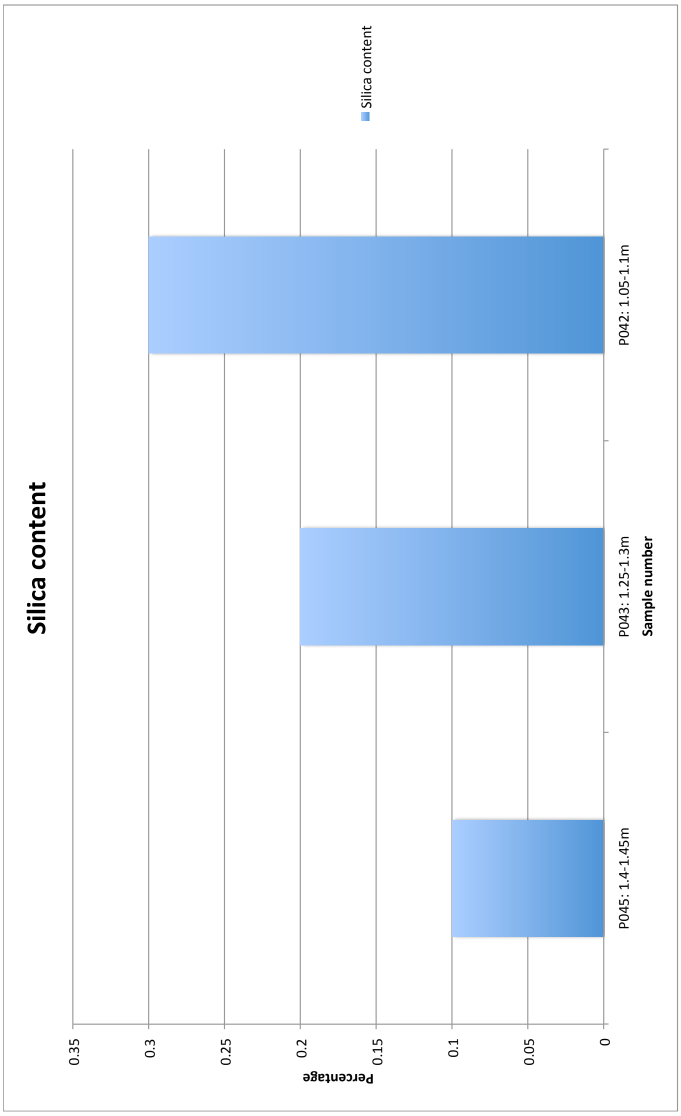


?Polycropping
Abundance
35000
30000
25000
20000
15000
10000
5000
0
P021: 5.4m/west OST1-1
P004: 5.1m/east OST1-1
P020: 5m/west OST1-1
P003: 4.9m/east OST1-1
P014: 5.2m/west OST1-1a
P013: 4.9m/west OST1-1a
P012: 4.6m/west OST1-2
P002: 4.5m/east OST1-2
P026: 3.8m/west OST1-2
P025: 3.0m/west OST1-2
P010: 2.7m/east OST1-2
P024: 2.5m/west OST1-2
P009: 2m/east OST1-2
P019: 4.5m/west OST1-3
P011: 4.3m/west OST1-3
P018: 4.2m/west OST1-3
P001: 3.4/east OST1-3
P023: 1.8m/west OST1-5
Sample number
Total cereals
Total ?Fruit

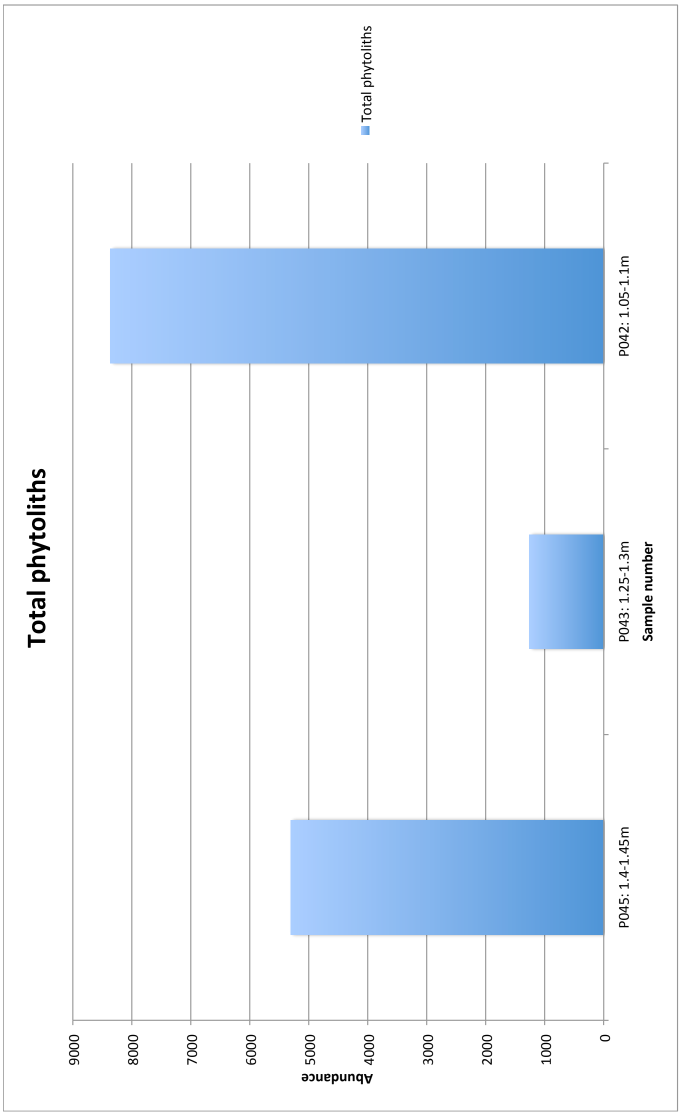

Jigsaw abundance (exc P023)
Abundance
0
10
20
30
40
50
60
70
80
Sample number
P021: 5.4m/west OST1-1
P004: 5.1m/east OST1-1
P020: 5m/west OST1-1
P003: 4.9m/east OST1-1
P014: 5.2m/west OST1-1a
P013: 4.9m/west OST1-1a
P012: 4.6m/west OST1-2
P002: 4.5m/east OST1-2
P026: 3.8m/west OST1-2
P025: 3.0m/west OST1-2
P010: 2.7m/east OST1-2
P024: 2.5m/west OST1-2
P009: 2m/east OST1-2
P019: 4.5m/west OST1-3
P011: 4.3m/west OST1-3
P018: 4.2m/west OST1-3
P001: 3.4/east OST1-3
Single cells
Multicells

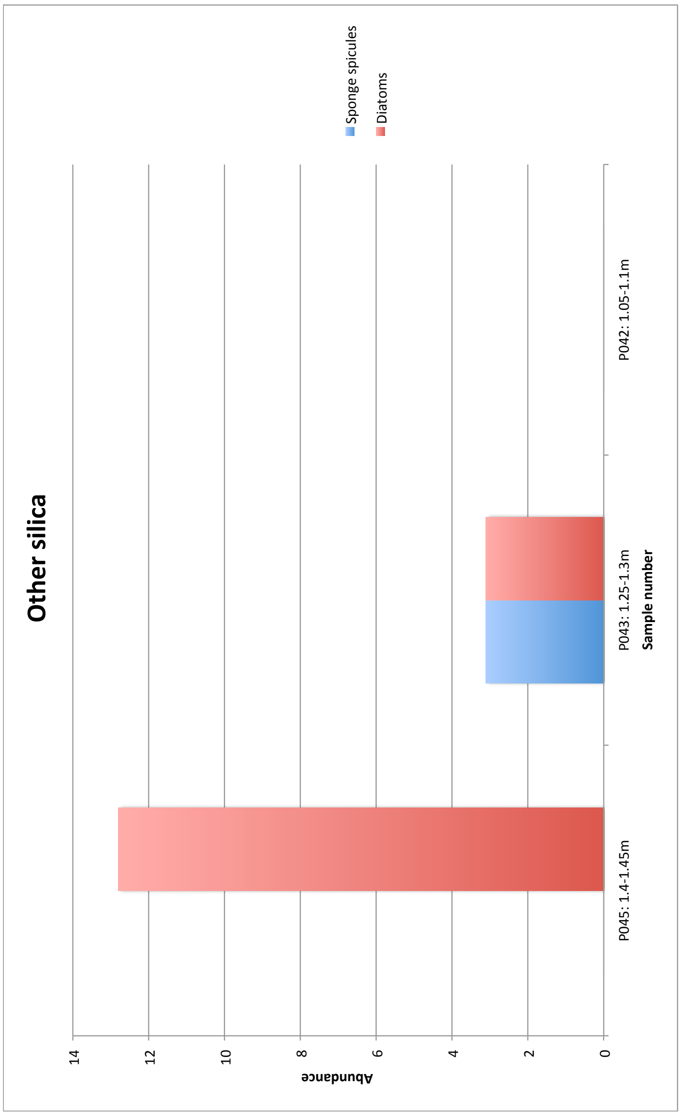


Jigsaw abundance
Single cells
Multicells
Abundance
300000
250000
200000
150000
100000
50000
0
Sample number
P023: 1.8m/west OST1-5
P001: 3.4/east OST1-3
P018: 4.2m/west OST1-3
P011: 4.3m/west OST1-3
P019: 4.5m/west OST1-2
P009: 2m/east OST1-2
P024: 2.5m/east OST1-2
P010: 2.7m/west OST1-2
P025: 3.0m/west OST1-2
P026: 3.8m/west OST1-2
P002: 4.5m/east OST1-2
P012: 4.6m/west OST1-1a
P013: 4.9m/west OST1-1a
P014: 5.2m/west OST1-1
P003: 4.9m/east OST1-1
P020: 5m/west OST1-1
P004: 5.1m/east OST1-1
P021: 5.4m/west OST1-1

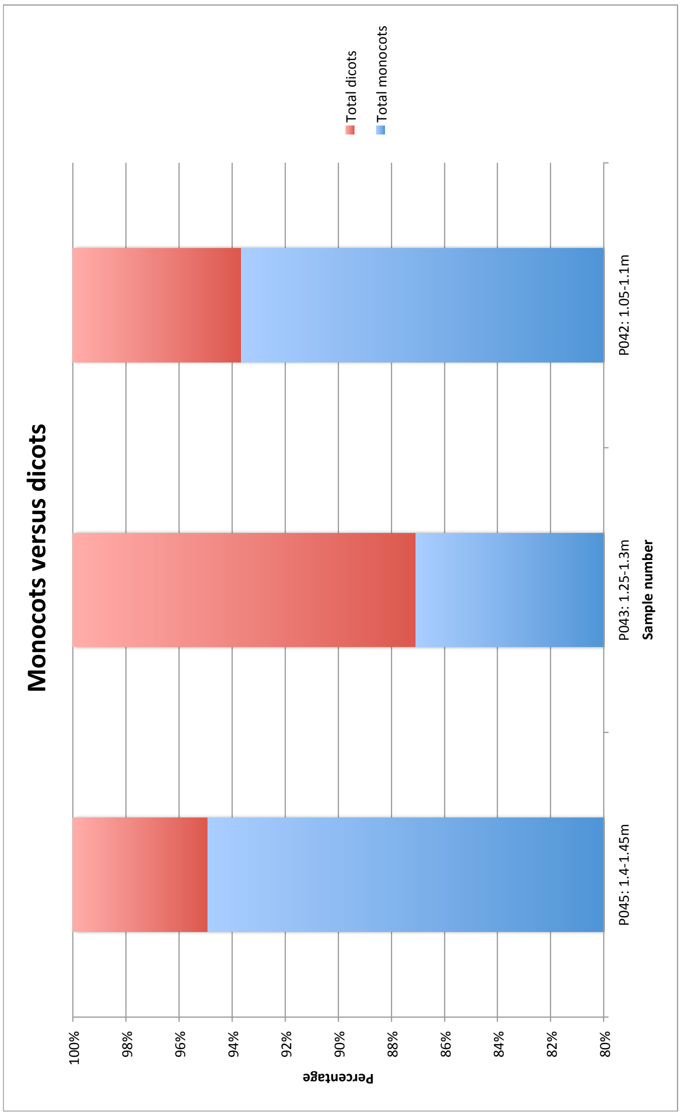


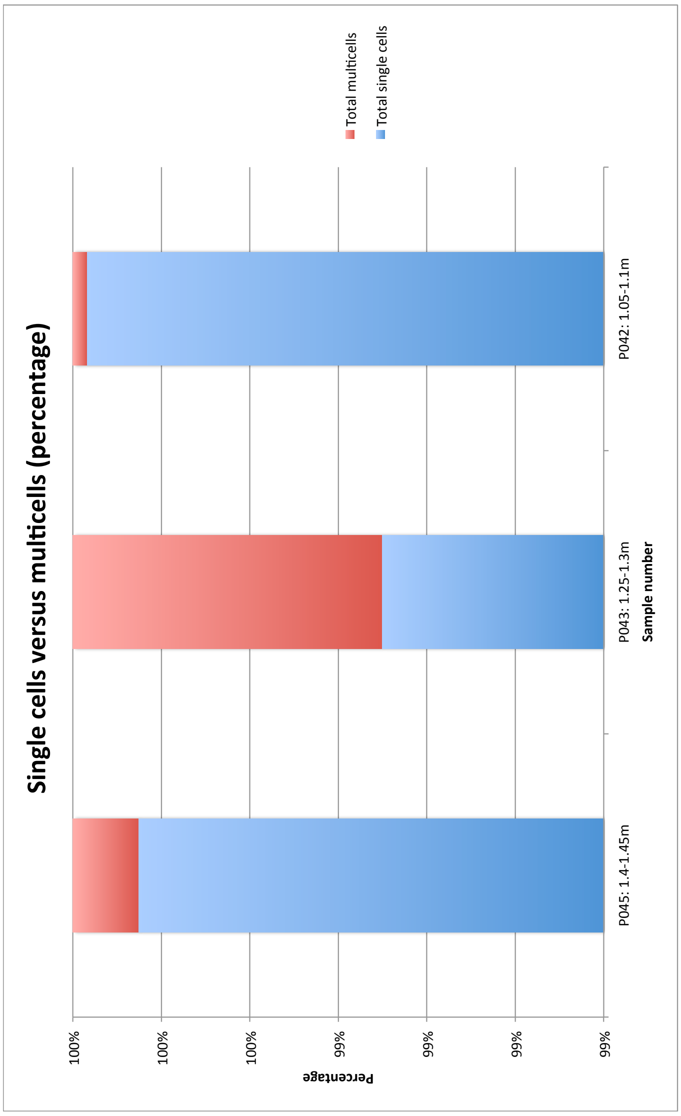
Silica content
Percentage
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
P045: 1.4-1.45m
P043: 1.25-1.3m
P042: 1.05-1.1m
Sample number
Silica content


Total phytoliths
Abundance
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
P045: 1.4-1.45m
P043: 1.25-1.3m
P042: 1.05-1.1m
Sample number
Total phytoliths

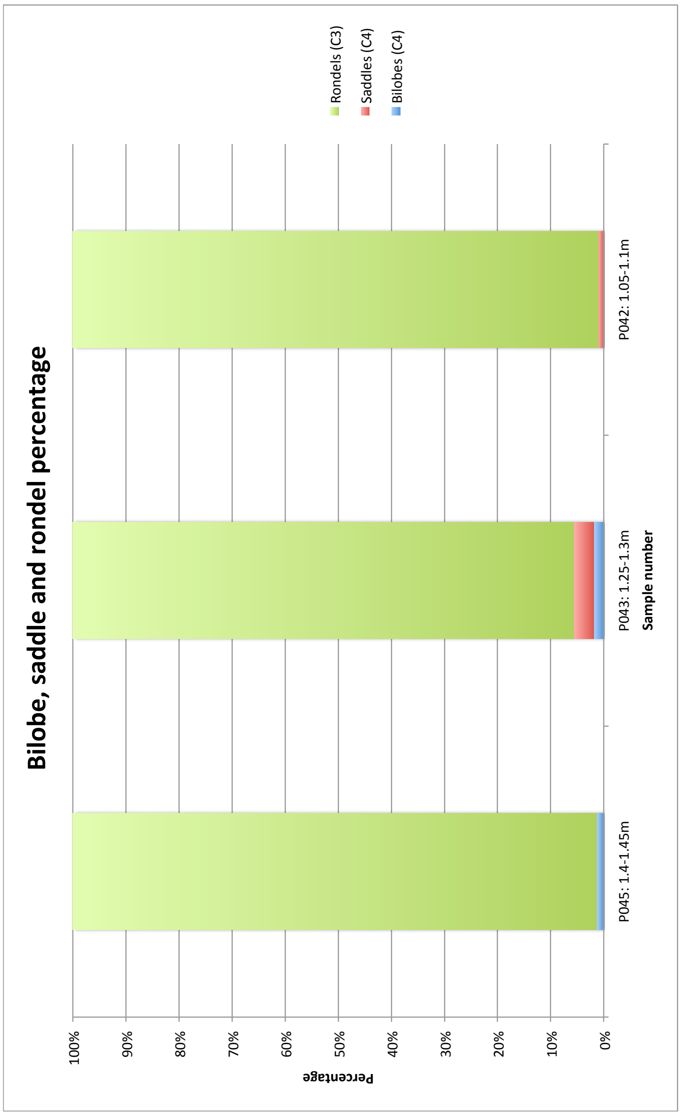


Other silica
Abundance
14
12
10
8
6
4
2
0
P045: 1.4-1.45m
P043: 1.25-1.3m
P042: 1.05-1.1m
Sample number
Sponge spicules
Diatoms

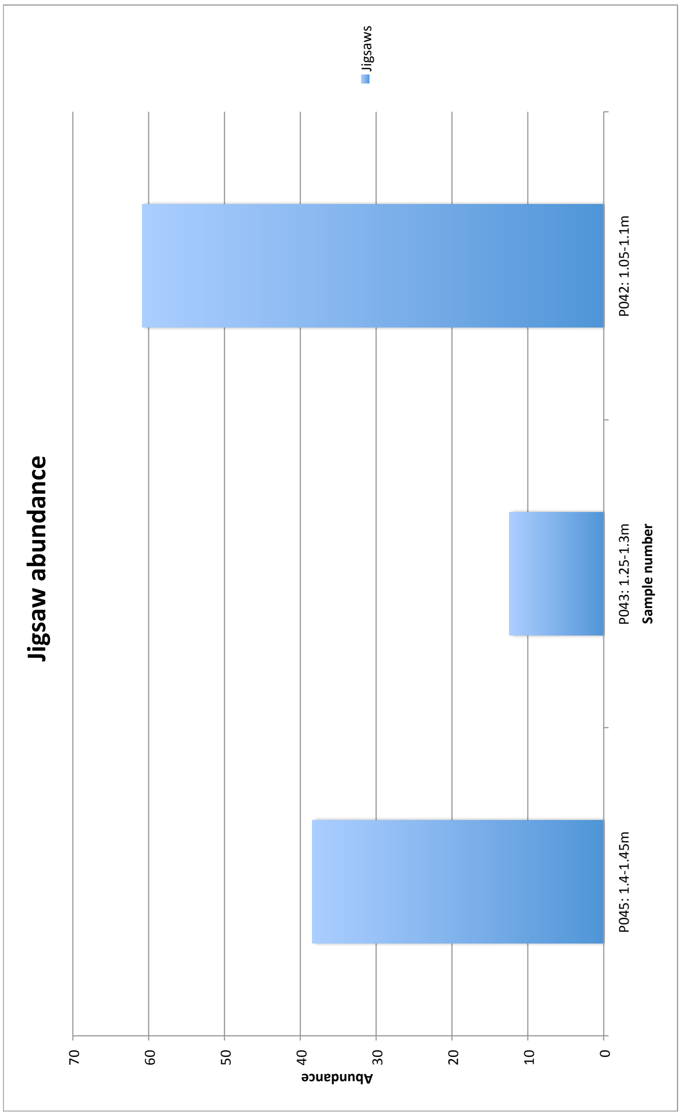

Monocots versus dicots
Total dicots
Total monocots
Percentage
100%
98%
96%
94%
92%
90%
88%
86%
84%
82%
80%
P045: 1.4-1.45m
P043: 1.25-1.3m
P042: 1.05-1.1m
Sample number



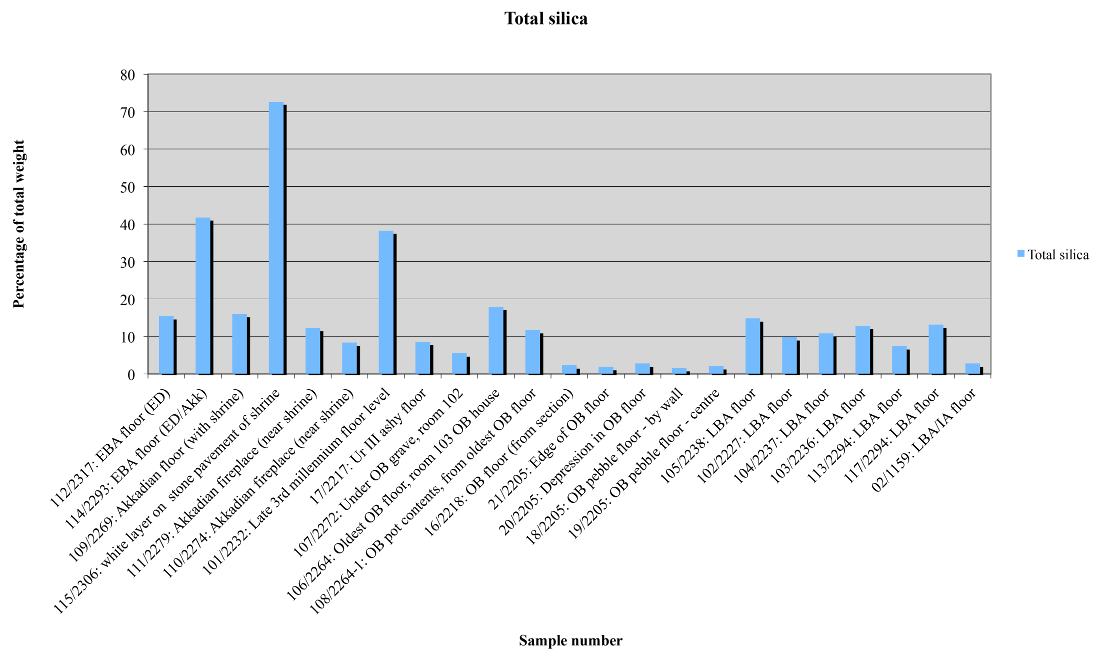
Single cells versus multicells (percentage)
Percentage
100%
100%
100%
99%
99%
99%
99%
P045: 1.4-1.45m
P043: 1.25-1.3m
P042: 1.05-1.1m
Sample number
Total multicells
Total single cells

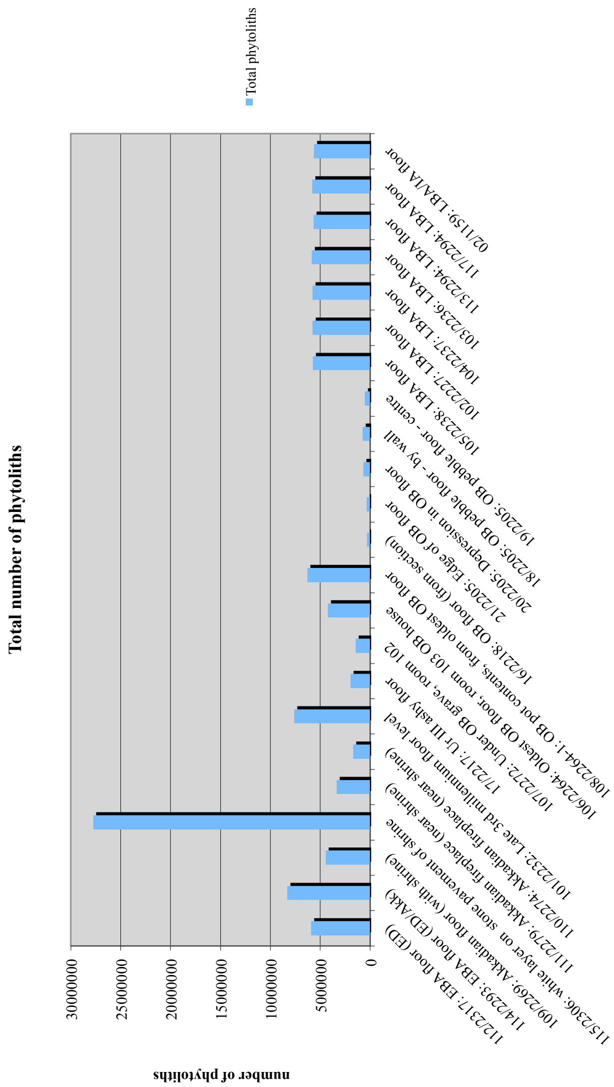


Bilobe, saddle and rondel percentage
Percentage
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
P045: 1.4-1.45m
P043: 1.25-1.3m
P042: 1.05-1.1m
Sample number
Rondels (C3)
Saddles (C4)
Bilobes (C4)


Jigsaw abundance
Abundance
0
10
20
30
40
50
60
70
P045: 1.4-1.45m
P043: 1.25-1.3m
P042: 1.05-1.1m
Sample number
Jigsaws

J.2 Onsite histograms


Total silica
Percentage of total weight
80
70
60
50
40
30
20
10
0
112/2317: EBA floor (ED)
114/2293: EBA floor (ED/Akk)
109/2269: Akkadian floor (with shrine)
115/2306: white layer on stone pavement of shrine
111/2279: Akkadian fireplace (near shrine)
110/2274: Akkadian fireplace (near shrine)
101/2232: Late 3rd millennium floor level
17/2217: Ur III ashy floor
107/2272: Under OB grave, room 102
106/2264: Oldest OB floor, room 103 OB house
108/2264-1: OB pot contents, from oldest OB floor
16/2218: OB floor (from section)
21/2205: Edge of OB floor
20/2205: Depression in OB floor
18/2205: OB pebble floor - by wall
19/2205: OB pebble floor - centre
105/2238: LBA floor
102/2227: LBA floor
104/2237: LBA floor
103/2236: LBA floor
113/2294: LBA floor
117/2294: LBA floor
02/1159: LBA/IA floor
Sample number
Total silica



Total number of phytoliths
number of phytoliths
0
5000000
10000000
15000000
20000000
25000000
30000000
Sample number
Total phytoliths
112/2317: EBA floor (ED)
114/2293: EBA floor (ED/Akk)
109/2269: Akkadian floor (with shrine)
115/2306: white layer on stone pavement of shrine
111/2279: Akkadian fireplace (near shrine)
110/2274: Akkadian fireplace (near shrine)
101/2232: Late 3rd millennium floor level
17/2217: Ur III ashy floor
107/2272: Under OB grave, room 102
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108/2264-1: OB pot contents, from oldest OB floor
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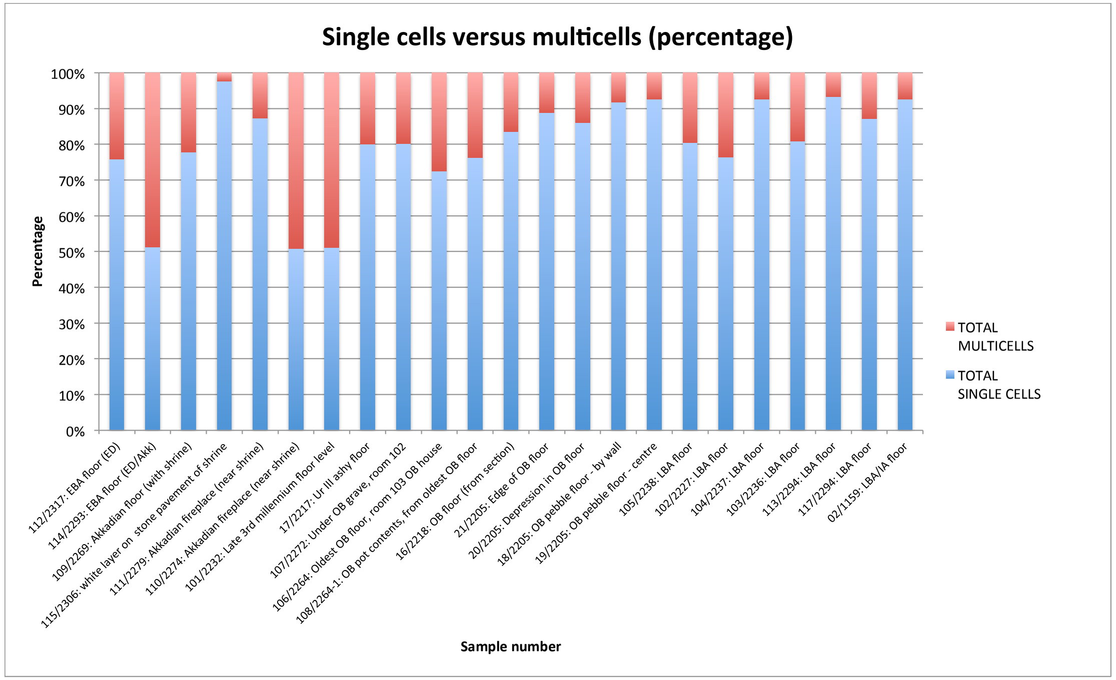
21/2205: Edge of OB floor
20/2205: Depression in OB floor
18/2205: OB pebble floor - by wall
19/2205: OB pebble floor - centre
105/2238: LBA floor
102/2227: LBA floor
104/2237: LBA floor
103/2236: LBA floor
113/2294: LBA floor
117/2294: LBA floor
02/1159: LBA/IA floor



Single cells versus multicells (percentage)
Percentage
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
112/2317: EBA floor (ED)
114/2293: EBA floor (ED/Akk)
109/2269: Akkadian floor (with shrine)
115/2306: white layer on stone pavement of shrine
111/2279: Akkadian fireplace (near shrine)
110/2274: Akkadian fireplace (near shrine)
101/2232: Late 3rd millennium floor level
17/2217: Ur III ashy floor
107/2272: Under OB grave, room 102
106/2264: Oldest OB floor, room 103 OB house
108/2264-1: OB pot contents, from oldest OB floor
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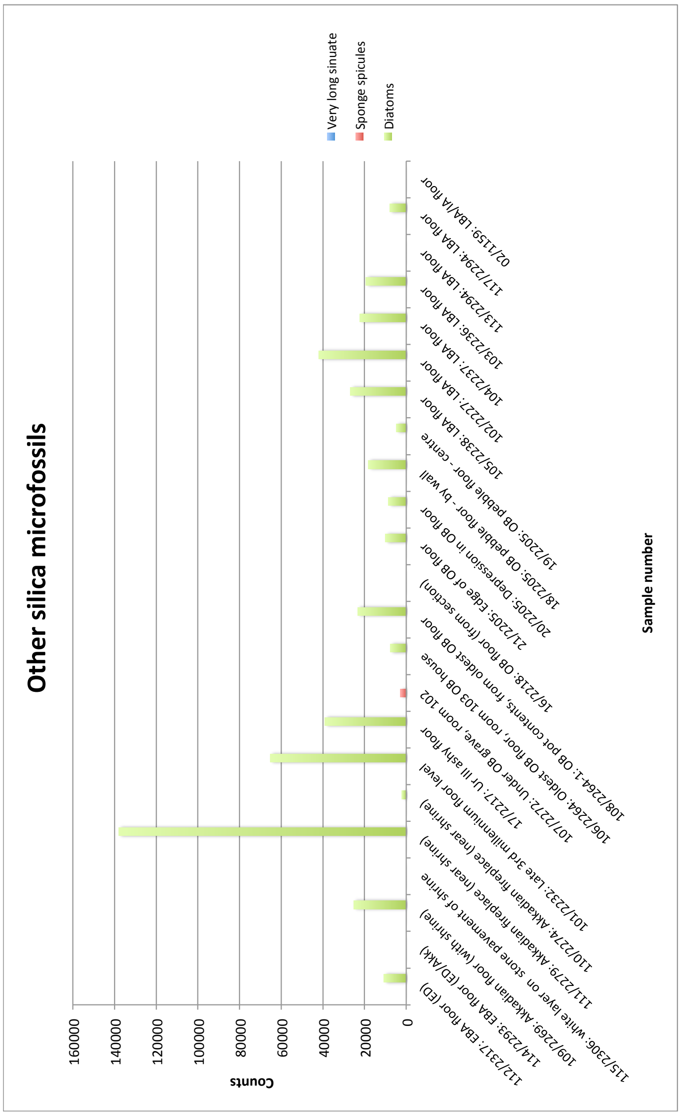
21/2205: Edge of OB floor
20/2205: Depression in OB floor
18/2205: OB pebble floor - by wall
19/2205: OB pebble floor - centre
105/2238: LBA floor
102/2227: LBA floor
104/2237: LBA floor
103/2236: LBA floor
113/2294: LBA floor
117/2294: LBA floor
02/1159: LBA/IA floor
Sample number
TOTAL MULTICELLS
TOTAL SINGLE CELLS


Other silica microfossils
Counts
160000
140000
120000
100000
80000
60000
40000
20000
0
112/2317: EBA floor (ED)
114/2293: EBA floor (ED/Akk)
109/2269: Akkadian floor (with shrine)
115/2306: white layer on stone pavement of shrine
111/2279: Akkadian fireplace (near shrine)
110/2274: Akkadian fireplace (near shrine)
101/2232: Late 3rd millennium floor level
17/2217: Ur III ashy floor
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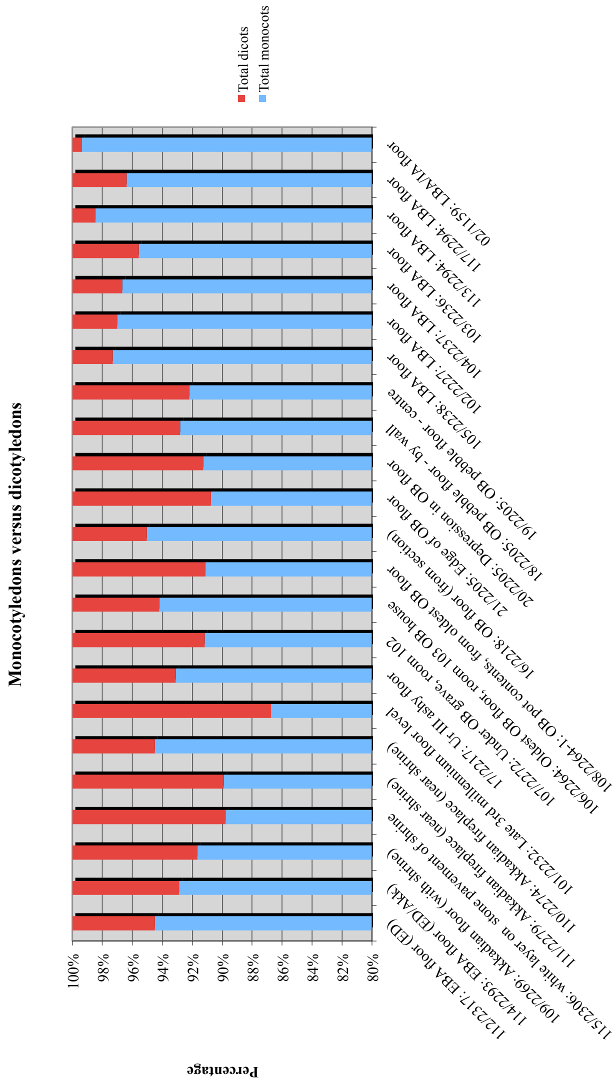
20/2205: Depression in OB floor
18/2205: OB pebble floor - by wall
19/2205: OB pebble floor - centre
105/2238: LBA floor
102/2227: LBA floor
104/2237: LBA floor
103/2236: LBA floor
113/2294: LBA floor
117/2294: LBA floor
02/1159: LBA/IA floor
Sample number
Very long sinuate
Sponge spicules
Diatoms


Monocotyledons versus dicotyledons
Total dicots
Total monocots
Percentage
100%
98%
96%
94%
92%
90%
88%
86%
84%
82%
80%
Sample number
02/1159: LBA/IA floor
117/2294: LBA floor
113/2294: LBA floor
103/2236: LBA floor
104/2237: LBA floor
102/2227: LBA floor
105/2238: LBA floor - centre
19/2205: OB pebble floor - by wall
18/2205: OB pebble floor
20/2205: Depression in OB floor
21/2205: Edge of OB floor
16/2218: OB floor (from section)
108/2264-1: OB pot contents, from oldest OB floor
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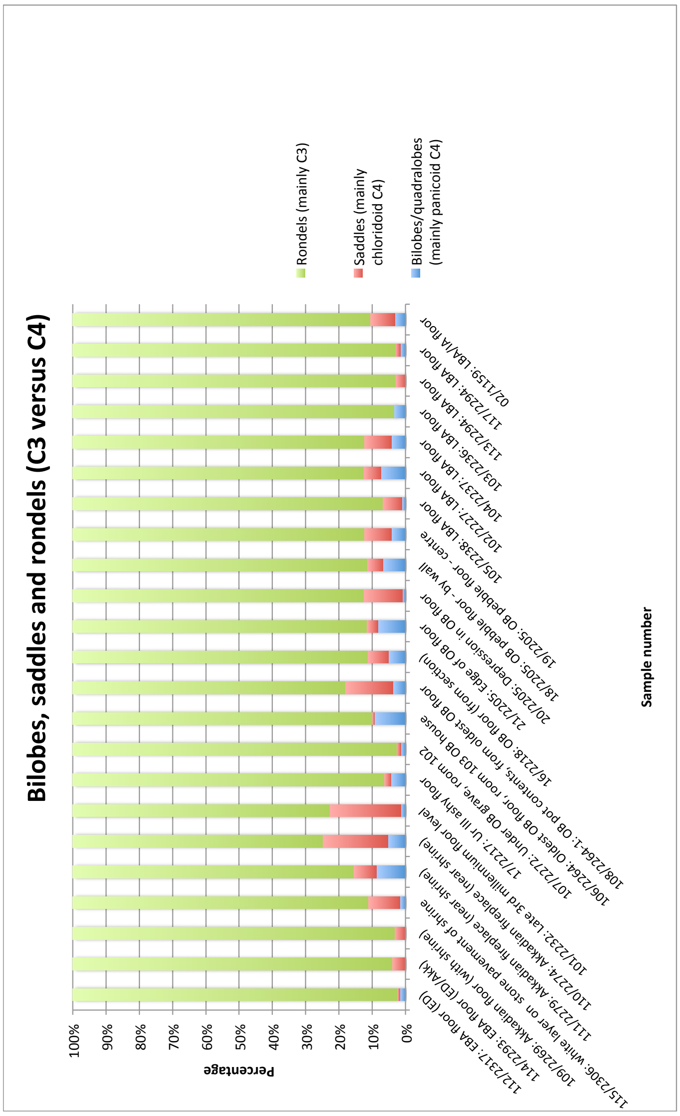
107/2272: Under OB grave, room 102
17/2217: Ur III ashy floor
101/2232: Late 3rd millennium floor level
110/2274: Akkadian fireplace (near shrine)
111/2279: Akkadian fireplace (near shrine)
115/2306: white layer on stone pavement of shrine
109/2269: Akkadian floor (with shrine)
114/2293: EBA floor (ED/Akk)
112/2317: EBA floor (ED)



Bilobes, saddles and rondels (C3 versus C4)
Percentage
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
112/2317: EBA floor (ED)
114/2293: EBA floor (ED/Akk)
109/2269: Akkadian floor (with shrine)
115/2306: white layer on stone pavement of shrine
111/2279: Akkadian fireplace (near shrine)
110/2274: Akkadian fireplace (near shrine)
101/2232: Late 3rd millennium floor level
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16/2218: OB floor (from section)
21/2205: Edge of OB floor
20/2205: Depression in OB floor
18/2205: OB pebble floor - by wall
19/2205: OB pebble floor - centre
105/2238: LBA floor
102/2227: LBA floor
104/2237: LBA floor
103/2236: LBA floor
113/2294: LBA floor
117/2294: LBA floor
02/1159: LBA/IA floor
Sample number
Rondels (mainly C3)
Saddles (mainly chloridoid C4)
Bilobes/quadralobes (mainly panicoid C4)